



P A C I F I C R E G I O N

SCIENCE REVIEW

1989 • 1990



Fisheries
and Oceans

Pêches
et Océans

Canada

P A C I F I C R E G I O N

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This report describes the programs and activities of the Science Sector, Pacific Region, Department of Fisheries and Oceans during the fiscal year 1989/90.

It reviews the activities of the Biological Sciences Branch, Physical and Chemical Sciences, and Hydrography. Science facilities include the Pacific Biological Station, the Institute of Ocean Sciences, the West Vancouver Laboratory, and the Cultus Lake Laboratory.

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Contents

Science Review
1989/90

i

Introduction	1
Institute of Ocean Sciences	
Hydrography	2
Field Hydrography	2
Marine Cartography	3
Tides and Currents	5
Physical and Chemical Sciences	9
Ocean Physics	9
Ocean Chemistry	13
Ocean Climatic Chemistry	14
Data Assessment	15
Ocean Ecology (See Biological Sciences)	
Biological Sciences Branch	17
Salmon Production Research	17
Salmon Dynamics Research	22
Salmon Habitat Research	29
Groundfish Research	33
Fish Age Determination	43
Herring Research	44
Shellfish Research	48
Ocean Ecology	53
Aquaculture Division	57
Biotechnology, Genetics and Nutrition Research	57
Fish Culture Research	60
Fish Health and Parasitology Research	61
Science Support	67
Marine Division	67
Scientific Computing	69
Communications	70
Management Services Branch/Personnel Branch	71

**Science Review
1989/90**

ii

Publications

Institute of Ocean Sciences
Biological Sciences Branch

Permanent Staff

73

73

76

97

Introduction

Science Review
1989/90

1

A full spectrum of science activities was carried out at the Pacific Biological Station (PBS), Nanaimo; the Institute of Ocean Sciences (IOS), Sidney; the West Vancouver Laboratory (WVL); and satellite facilities located at Cultus Lake, Vancouver and elsewhere. Studies in support of the Department of Fisheries and Oceans mandate addressed priority research topics related to the fisheries resource and oceans and hydrographic activities on the West Coast, inland waterways and the Western Arctic.

This review describes programs carried out by the Science Branch in the Pacific Region. Additional details can be obtained by contacting the appropriate laboratory directly. Emphasis in 1989/90 was placed on strengthening of effort in the planning process for fisheries and oceanographic climate-related research, high seas studies and involvement in international negotiations related to the squid driftnet fishery in the North Pacific, and intensified work on dioxins and other contaminant problems. Attempts were made to strengthen scientific cooperation with Pacific Rim nations including, Japan, China, the U.S.S.R. and the U.S.A. through involvement in negotiations for a future science treaty and other related initiatives.

DFO science activities in the Pacific Region are administered by a Regional Director of Science and a Science Executive staffed by Branch Directors. National coordination with the other five regions is achieved through a National Science Director's Committee. Consultation with a wide variety of clients takes place at all levels. Visiting faculty, graduate students and other individuals work closely with regional laboratories. Research vessel support is also provided to the university community and other government departments and institutions as part of a comprehensive program of science vessel operations.

Hydrography

The Canadian Hydrographic Service (CHS) fulfills DFO's mandate to provide accurate up-to-date nautical charts and related publications, such as Sailing Directions and Tide Tables, for use by mariners, recreational boaters and others. The Pacific Region's area of responsibility extends from 200 miles seaward of the coast, east to the Saskatchewan/Manitoba border, and includes the Western Arctic. Field programs are carried out to collect the necessary information which is processed, published and distributed through a network of chart dealers.

Field Hydrography

Field Surveys

Hydrographers carried out surveys working from the J.P. TULLY (*G.H. Eaton*) in the Western Arctic, the barge PENDER (*M.V. Woods*) on the west coast of Vancouver Island, and from the RICHARDSON on the north coast of B.C. Revisory surveys were also made in southwestern B.C. to update charts and to respond to requests from the marine community.

A series of surveys in the Beaufort Sea initiated in 1985 to define the hydrography in the area of potential hydrocarbon pipeline development were completed. The TULLY and her launches ran a total of 29,000 line kilometres of sounding in an area north of Richards Island and around Amaliguk. Ocean bathymetry measurements were collected on the passage to and from Patricia Bay to the Arctic. Other projects included an investigation of the erosion of abandoned artificial islands (*K. Czotter*) in conjunction with crew of the C.C.G.S. NAHIDIK, and evaluations of soundings (*G. Richardson*) and satellite positioning equipment. (*G. Eaton*)

Surveys were completed in Clayoquot Sound on the west coast of Vancouver Island for new charts 3673 and 3674. In September, the barge PENDER was towed to Nootka Sound to begin work on a survey of Muchalat Inlet. (*Contact: A.R. Mortimer*)

The small survey party on the RICHARDSON worked on two survey projects on the north coast in 1989. Survey work in Mathieson Channel north of Bella Bella was initiated to replace surveys conducted in 1916. Work also started on surveys in Houston-Stewart Passage in the Queen Charlotte Islands at the southern extremity of the new national park on Moresby Island. (*Contact: A.R. Mortimer*)

Revisory Surveys

Science Review
1989/90

Minor surveys for new editions of charts or in response to requests from chart users or other government departments were made in Sidney, Long Harbour (Saltspring Island), Squamish, and in Burrard Inlet and False Creek where a new chart is to be published.

3

Support survey work was carried out for oceanographers beginning a program to study the North Water between Baffin Island and Greenland. This entailed a reconnaissance survey of the Carey Islands off Thule and production of a photogrammetric plot and hydrographic field sheet. (*Contact: A.R. Mortimer*)

Contracted Surveys

The Arrow Lakes survey work was undertaken in response to requests from local organizations and individuals to assist in development of the Arrow Lakes as a tourist destination. It is planned to publish a series of small craft charts of the lakes and adjacent portions of the Columbia River. This year's hydrographic survey contract was awarded to Terra Surveys. Field work was carried out during the summer.
(*Contact: B.M. Lusk*)

Marine Cartography

The Chart Production and Distribution Section ensures that surveys and all other pertinent data are processed for publication and maintains an up-to-date supply of all charts and publications available for distribution.

New Charts Produced in 1989/90

No.	Title
3545	Johnstone Strait, Port Neville to/à Robson Bight
3546	Broughton Strait
3547	Queen Charlotte Strait, Eastern Portion/Partie Est
3548	Queen Charlotte Strait, Central Portion/Partie Centrale
3891	Skidegate Channel

Five New Charts were released. Four of these are a continuation of the 1:40 000 series through Johnstone Strait and into Queen Charlotte Strait. The other was a chart of Skidegate Channel and the western approaches. Four Reruns were generated, three for stock purposes, and one to replace a defective printing. Eleven Chart Amendment Patches were produced to revise existing editions and one overprint was processed to incorporate an excessive number of hand amendment actions.

The replacement Kongsberg plotting table from SYSCAN was received in September and operation training was given to four cartographers following installation. One hundred and thirty plots were produced on the table this year.

Eight marine cartographers received CARIS (Computer Aided Resource Information System) training in the Region. A concerted effort is being made to update existing digital chart files. This program is being blended into one which is designed to make all cartographers more familiar with the CARIS/CARED (Computer Assisted Resource Editor) system.

Terra Surveys Ltd. was contracted to digitize compilation manuscripts. Digital data for two standard charts and six strip charts have been received.

The Hydrographic Data Centre processed 926 plans and 348 MAREPS (Canadian Power and Sail Squadron Marine Reports). The unit also fulfilled requests for duplication of 324 field survey documents.

The Navigation Information Unit promulgated 137 Notices to Mariners, prepared 43 Navigational Aids Copies and assessed over 1,100 NWPA (Navigable Waters Protection Act) plans for relevant charting action.

The Photomechanical Unit processed 6,000 exposures for Chart Production and a further 1,250 for other Institute personnel. One hundred and fifty oblique photographs were taken of the Fraser River, Howe Sound, the Sunshine Coast and Port Alberni for Sailing Directions.

Two cartographers successfully completed the Cartography II course in Ottawa. An additional two cartographers conducted a two day pre-revisory survey familiarization helicopter flight of Jervis Inlet and Desolation Sound.

Promotional activities in 1989/90 included displays for a local shopping mall's 'Salute to the Sea' week, the launching of the MV DELTA, the Vancouver and Victoria Boat Shows and the Canadian Power and Sail Squadron Conference in Victoria.

Dealership inspections were conducted in the State of Oregon, and in Vancouver and Victoria. A total of eleven facilities were visited as part of an ongoing program to ensure that dealership requirements are being met.

Chart and publication sales generated a gross revenue of \$979K.
(Contact: W.S. Crowther)

Tides and Currents

Science Review
1989/90

5

A network of twenty-eight tide gauges was maintained on the British Columbia coast and in the Western Arctic. The network consists of sixteen permanent stations on the B.C. coast administered jointly with Water Survey of Canada, six stations in the Western Arctic, and five long term temporary stations on Vancouver Island operated in support of a Pacific Geoscience Centre study of crustal movement. Several temporary gauges were also operated in support of hydrographic surveys or special projects.

The data from these stations are used for a wide range of studies and applications including sea level change, storm surges, fish habitat and physical oceanography. In addition, the data are used in engineering studies, for hydrographic surveys, tide and current tables, and on occasion, in litigation. (*Contact: F.E. Stephenson*)

Tsunami warning stations were operated at Langara Island, Winter Harbour, and Bamfield to support Canada's commitment to the Tsunami Warning System in the Pacific. A Meteor Burst VHF radio communication link was installed at Bamfield, providing a second, independent means of acquiring the water level information. Work is proceeding on the new tsunami warning station in Rennell Sound, which is expected to be operational in September 1990. (*Contact: F.E. Stephenson*)

Surveys of the tidal streams in hazardous and fast flowing narrow passes on the B.C. coast continued. These strong currents, with speeds up to 16 knots, pose a serious hazard to navigation and preclude the use of conventional current meters. The field observational program in the Discovery Passage area was completed successfully this year although one current meter mooring was lost to towing traffic off Campbell River. Further analysis of the data awaits completion of the conversion of the specialized software to the new Apollo computer network. This software is being restructured and refined to improve the modelling of the affects of acceleration and the change in friction with the depth of water in the channel. (*Contact: M.J. Woodward*)

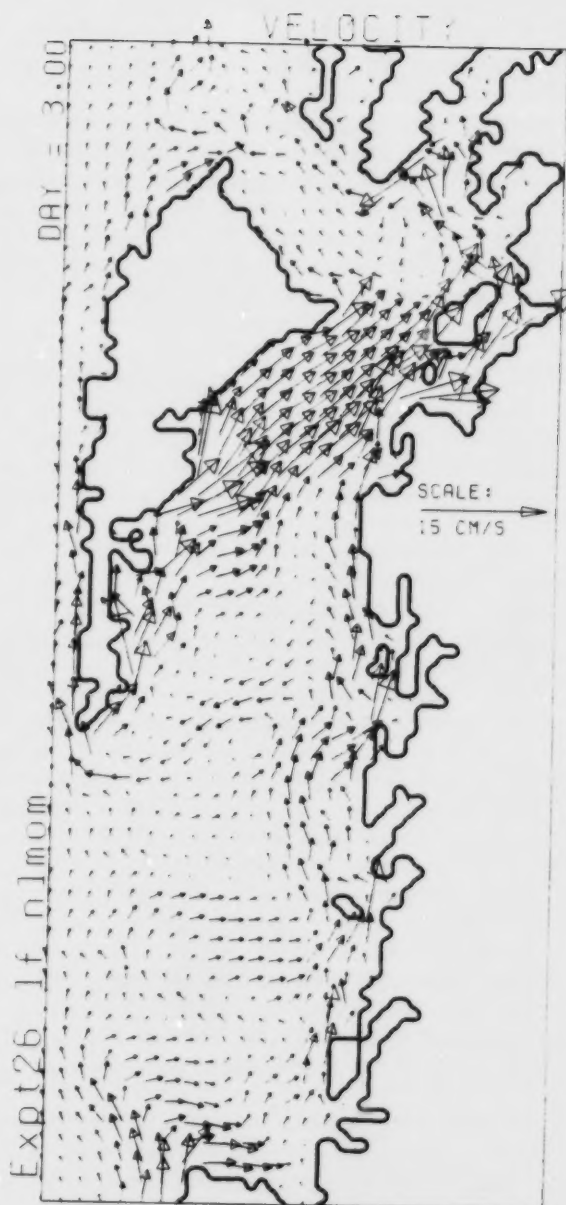
Studies of the salinity intrusion in the Fraser and Campbell estuaries continued. Minor oil spills in Juan de Fuca Strait were also monitored. (*Contact: A.B. Ages*)

A numerical model to support computations of the volume transport of salt water into the Campbell River estuary was completed. The physical analysis was requested to examine the effect of artificial changes in the estuary's topography upon the salmonid feeding grounds. (*Contacts: A.B. Ages, A.L. Woollard*)

Verification of an acoustic flow measurement system developed under contract by a local firm was undertaken in the trifurcation of the Fraser River near New Westminster. (Contact: A.B. Ages)

Program staff participated in the Ocean Physics Surface Wave Processes Program, a study of the circulation of the upper 50 metres of the ocean, to resolve the processes responsible for transporting heat and momentum between the sea and air. It has been known for years that long horizontal rolls or vortices form in the ocean when winds and waves are high, but it has not been possible to observe the rate of heat transfer by these vortices, (Langmuir cells). During a cruise of the CSS PARIZEAU in early 1990, scientists examined the Langmuir cells and the heat flux using special profiling instruments developed at IOS. (Contact: W.R. Crawford)

Surface-drifter studies of the west coast of Vancouver Island were completed and preparations began for a five year program to look at the currents in Hecate Strait and Dixon Entrance. The first field season will begin in the summer of 1990 with the deployment of surface drifters and current meters in Southern Hecate Strait. (Contacts: W.R. Crawford, M.J. Woodward)



Residual circulation in northern British Columbia. Vectors represent ocean currents driven by a wind from the southeast.

Diving Unit

Science Review
1989/90

7

A total of 103 dives were made in support of activities at IOS, including dives to install or recover bottom mounted pressure gauges in the Western Arctic and on the B.C. coast. Dives were also made at permanent tide gauge stations to inspect stilling wells and underwater bracing, clean tide staffs, carry out repairs and, in one case, search for a tide gauge after it collapsed into the water.

Dives were also made to install and recover samples from sediment traps, to carry out shoal exams and install tide gauges, and to inspect hulls, propellers and zincs on the ships and barges.

A program of diver recertification and upgrading was initiated during the year. The recertification system is designed to bring IOS more in line with CAUS (Canadian Association for Underwater Science) standards, and to bring more divers up to the Rescue Diver level. (*Contact: F.E. Stephenson*)

Institute Electronics / Precision Machine Shop

CSAIL, an environmental logging network, has been installed on all vessels in the research fleet. Some introduction problems were encountered but the system promises to standardize shipboard logging. A regular bimonthly data publication schedule was established.

A gelled electrolyte (Gel Cell) battery capacity analyzer was developed to determine the true capacity of batteries used to power remote trisponder sites.

The Institute Electronics Group was designated the national incoming inspection authority for 30 launch computer systems (ISAHS) purchased by CHS to provide real time navigation and data logging. In preparation for delivery of the systems, a data simulator was developed, a database written to assemble test results and software test procedures were developed. (*Contact: E.W. Hinds*)

Sonar Systems

A correlation module for echo sounders which transmits a pulse burst instead of a single pulse was developed. This makes the signal detection far easier to accomplish, and translates into dramatically better depths at the same frequency, or achieving the same depth at higher resolution (higher frequency).

In fisheries acoustics research, there was qualitative agreement in fish patchiness between net samples and acoustic samples, in contrast to previous years. Acoustic pingers were inserted into adult salmon to monitor behaviour, and preliminary studies of fish target strength were conducted. (*Contact: J.L. Galloway*)

Underwater Vehicles

Significant progress was made with the remotely operated vehicle (ROV). Numerous dives were carried out on both coasts throughout the year. The vehicle cage is being downsized to facilitate handling, stereo video is being developed, the manipulator control system is being modified (resolved motion control), and a smaller diameter cable was purchased. (*Contact: G.R. Smith*)

Industrial Liaison

Two numerical models were commissioned; a baroclinic model in Barkley Sound, and a barotropic model for the waters off Sidney. A model, coupled with some field observations, appears to be the preferred way to achieve a better understanding of surface current circulation.

Scientists and engineers from IOS participated in the B.C. "Scientists in the Schools" program. (*Contact: T.A. Curran*)

Physical and Chemical Sciences

Science Review
1989/90

9

The Physical and Chemical Sciences Branch collects much of the basic knowledge needed to use the oceans wisely and safely. This ranges from methods for predicting currents, tides, waves and tsunamis to an understanding of the complex chemical reactions which occur when pollutants enter the sea. The information collected is disseminated to users through scientific publications, consultations and scientific advice on specific topics.

Ocean Physics

The oceanographers of the Ocean Physics Division, the largest Canadian oceanographic group working in the Pacific and western Arctic, measure the physical behaviour of the ocean, including temperature, salinity, currents, ice, sea level and waves. They attempt to find explanations for conditions observed and use the resulting information to forecast changes.

Fjords and Narrow Channels

A study of oceanic factors controlling dissolved oxygen levels in Neroutsos Inlet, where pulp mill discharges have been linked with dissolved oxygen depletion, was completed. Results of the study indicate that wind-driven currents are the most important natural factor in controlling oxygen levels. However, the observed variations in oxygen could not be explained on the basis of information resulting from the study.
(Contact: D.J. Stucchi)

Although vertical mixing in the water column is extremely difficult to measure directly, quantitative measurements are required to predict the dispersal direction of dissolved materials. A new technique was developed which uses acoustic measurements of the small scale vertical water motion. A ship-mounted prototype is being tested over a wide range of conditions in local waters. If successful, this technique will permit the rapid surveys of mixing needed to determine mixing variation in space and time, and to determine the best method for modelling mixing rates in fjords. (Contact: A.E. Gargett)

A three dimensional numerical model of flow and water properties is being developed for the Strait of Georgia. This project, which is using expertise developed with earlier numerical models of tides in the area, is being carried out in cooperation with Seaconsult Marine Research and should improve predictions of the movement of pollutants.
(Contact: T.S. Murty)

Continental Shelf

The continental shelf area south and west of Vancouver Island has been studied most intensively because of its rich fishery resource and the concentration of marine traffic. Two major cooperative projects are underway in this area. Scientists from IOS and Biological Sciences Branch are working on the La Perouse Project, a ten year study directed at providing long-term physical and biological data for research on factors affecting year-to-year variations in Pacific herring, sablefish, Pacific hake and Pacific salmon stocks. A total of 7.4 'instrument years' were logged by moored instruments, 503 vertical profiles of temperature and salinity were taken and 51 plankton net hauls were completed in 1989/90. (*Contact: R.E. Thomson*)

The Marine Survival of Salmon (M.A.S.S.) Project is another multidisciplinary study examining oceanic factors affecting the survival of juvenile salmon from the west coast of Vancouver Island. Emphasis in 1989/90 was on interpretation of data collected in earlier years together with theoretical and modelling studies. A current meter mooring was maintained in Barkley Sound. Numerical models developed for M.A.S.S. were applied to correction of shipboard surveys for tidal currents, which changed during the time taken to make the survey. (*Contacts: H.J. Freeland, M.G. Foreman, J.F. Gower, A.E. Gargett*)

Another continental shelf area under study because of offshore oil and gas exploration in the area is the Beaufort Sea. The primary objective of the physical oceanography program in this area has been to improve the oceanographic information available for use in forecasting ice motion. Support for the program has come from the Program of Energy Research and Development (PERD). One approach has been to study the response of currents to forcing by winds and by moving atmospheric pressure fields. Measurements and numerical models have shown that stable current patterns are rare. More often, the current field is composed of rapidly changing small scale eddies and waves. This information is also required for prediction of movements of oil spills. (*Contact: H. Melling*)

Another approach has been to study the coupling between the ice and underlying water. The 'keels' of pressure ridges protrude below the surface of the ice, often by several metres, while the water immediately beneath the ice is frequently stratified with strong contrasts of temperature, salinity and density. As a result, drift of the ice relative to the water sets up internal waves, producing a completely different type of drag than that due to simple frictional effects. A field experiment was conducted using an array of current meters, satellite-tracked drift beacons and acoustic ice profilers to acquire a simultaneous data set for a full scale test of ideas developed through earlier field and model experiments. (*Contact: D.R. Topham*)

DFO has been a major contributor to the network of buoys monitoring waves on the Pacific coast. The resulting observations are transmitted to forecasters and stored in archives for climatological analyses. To acquire improved understanding of the physics of waves, research in 1989/90 concentrated on interpretation of data obtained from large

scale international experiments. An improved method was developed to determine wave directions from a commonly used wave buoy. This was used to examine wave field changes with shifts in wind direction. Theoretical work on the wave forces on floating sea ice was verified with observational data. (Contacts: D. Masson, A.E. Gargett)

Ongoing research into tsunami prediction produced an evaluation of tsunami amplitudes for the B.C. coast. (Contact: T.S. Murty)

Open Ocean

Current concern over global warming has intensified interest in the oceans and has prompted two major international scientific studies of ocean circulation and its effect on climate: the Tropical Ocean Global Atmosphere (TOGA) experiment and the World Ocean Circulation Experiment (WOCE). Ocean climate monitoring is carried out at 15 shore stations, which collect daily samples of surface ocean temperatures and, in some cases, salinities. Permanent tide gauges provide sea level records. Four times a year, a research vessel travels to the site of Ocean Weather Station P (50°N, 145°W) to continue the series of ocean property observations started 34 years ago, one of the world's longest series of open ocean observations. Analyses of these data show that the water appears to have become warmer and less saline at all depths. (Contacts: S. Tabata, H.J. Freeland)

Data from the North Pacific is being used to prepare an experimental series of monthly maps of climate conditions. Following signing of an agreement with the Pacific Oceanological Institute in Vladivostock, a series of cooperative cruises will be conducted from 1991-1996 to map ocean climate conditions in the northern North Pacific. (Contacts: M. Miyake, R.A. Lake)

Three techniques for measuring eddy strength are being applied to the northeast North Pacific. The paths followed by satellite-tracked drifting buoys often show meanders and loops which can be interpreted to indicate eddy strengths. One such study completed in 1989, in cooperation with the University of British Columbia, indicated the presence of several eddies apparently generated near the edge of the continental shelf and propagating southwestward at a speed of one to three kilometres per day. The currents associated with eddies cause small hills and valleys in the sea surface which can be measured by radar altimeters carried on satellites. Altimeter data from the U.S. Geosat satellite gave similar results to the drifting buoy study. These techniques only measure eddy behaviour near the surface, so a third study is trying to determine the depth of the eddies with current meter moorings. Because eddies pass very slowly, three years of data will be required to accumulate a representative sample. (Contacts: R.E. Thomson, J.F. Gower, H.J. Freeland)

Computer models of the upper ocean combining available 'real time' observations with previous knowledge of physical mechanisms of ocean circulation are being developed to produce more representative maps and forecasts. As there is insufficient data to map the eddy field, the

models must represent the effects of eddies by some approximation, depending upon the large scale features of ocean circulation. The Cox model, a widely-used ocean model, was tested to evaluate changes in results using different assumptions for vertical mixing of heat and salt. A theoretical model was developed to represent the effect of the interaction between an unknown eddy field and bottom topography on the large scale circulation. (Contacts: G. Holloway, M.G. Foreman)

Hydrothermal venting on the Juan de Fuca Ridge is being studied intensively by several Canadian and American groups. Plume velocity and backscatter were measured successfully using an acoustic doppler profiler towed at the depth of the plume, in cooperation with RD Instruments. High levels of backscatter in the upper part of the plume suggest an enhanced zooplankton concentration. (Contact: R.E. Thomson)

Observing Techniques

Acoustics research has proven particularly useful in studying the processes taking place at the ocean surface which are otherwise difficult to measure because of the strong motions associated with waves. In a joint experiment with the U.S.-manned spar buoy FLIP, a special instrument package carrying recording equipment, several hydrophones and a video camera was suspended 10 to 50 metres below a small surface buoy to study patterns of wave breaking, convection and heat and gas exchange through the surface. An improved understanding of these processes will permit more accurate estimation of the oceanic uptake of CO_2 .

The cracking sounds made by sea ice can be interpreted in terms of stresses in the ice and ice strength. The data obtained with an array of sound recorders suspended under the ice are also being used to study the propagation of cracks in relation to surface features and ice types. Fluctuations in sound transmitted across a turbulent flow can be used to estimate the mean velocity of the flow and the properties of the turbulent field. This work is being conducted in cooperation with the University of Victoria and the University of British Columbia with funding from PERD, NSERC (National Science and Engineering Research Council) and the U.S. Office of Naval Research. (Contact: D.M. Farmer)

Forecasting Methods

Numerical modelling is often the only practical method for examining the complex interactions of ocean processes. While model resolution is often limited by computer memory, the use of high resolution model grids only when required can reduce memory requirements. TRIGRID, an automated system for generation of irregular triangular grids for numerical modelling developed at IOS, is now in use in a number of North American and European laboratories. (Contact: R.F. Henry)

Ocean Chemistry

Science Review
1989/90

13

Staff in the Ocean Chemistry Division are attempting to understand the distribution and behaviour of chemical pollutants through the study of both artificial and natural compounds including heavy metals, oil, and polychlorinated hydrocarbons such as PCB's and dioxins.

In a new program of studies on dioxins, a sediment sampling and analysis program was conducted in Howe Sound to determine the rate at which present sediment concentrations of dioxins can be expected to diminish following implementation of new bleaching technology in area pulp mills. A study of lead isotopes in sediments in the Ballenas Basin of Georgia Strait provided information on sedimentation and burial rates since the introduction of leaded gasoline. A geochemical study of the transport of contaminants in the sediments of Alberni Inlet was also initiated. (*Contacts: W.J. Cretney, R.W. MacDonald*)

Fraser River Studies

A laboratory study of the effects of bleached kraft pulp mill effluent on juvenile chinook salmon at low temperatures in the Fraser River was conducted in cooperation with BSB. Although the fish survived well and appeared healthy, some developed liver abnormalities characteristic of bacterial kidney disease. (*Contact: I.H. Rogers*)

Resident fish from the South Arm of the Fraser River were sampled in the third year of a study examining the presence of chlorinated organic contaminants in the Fraser River estuary. Some fish from both North Arm and South Arm sites have been found to contain high levels of PCB's relative to the background population at the capture site. This probably reflects the mobility of fish within the system and highlights the need for more information on the movements of resident fish species within the estuary. (*Contact: I.H. Rogers*)

Northern Oil and Gas Activity Project (NOGAP), Beaufort Oceanography

A PERD-funded study of the degradation of dissolved oil by bacteria is underway. Degradation increases with the presence of particulates which provide attachment sites for the molecules. The effect of dispersants will be examined in 1990. (*Contact: W.J. Cretney*)

The scales, boundaries and water masses dominating the Mackenzie Shelf were determined. Using a simple geochemical model which reveals the cycling of freshwater stocks between winter and summer it is possible to infer the importance of runoff and ice melt to the shelf, not only as a source of water, but also as a control on the production of other ice-mediated water masses. Fresh water was used to establish residence times of surface water masses on the shelf in the first step towards determining zones likely to be affected by the oil and gas industry. (*Contact: R.W. Macdonald*)

Ocean Climatic Chemistry

The Centre for Ocean Climatic Chemistry studies the ways in which the ocean absorbs or gives off substances such as CO₂, freon, methane, and other radiatively active gases, which can affect the climate. Measurements of upper ocean levels of CO₂, carbon and nutrients are taken to determine variations in gas exchange between locations, at different times of the year and under different conditions of biological productivity.

The development and comparison of measurement techniques is an important activity. Data from different parts of the world cannot be combined to make global estimates if there are discrepancies where the measurements overlap. The methods used at IOS to measure dissolved inorganic carbon (DIC) were shown to be comparable with other leading laboratories. A seawater CO₂ standard for use in comparisons among laboratories was prepared. (Contact: C.S. Wong)

The sediment trap and air/sea CO₂ exchange time series data from Ocean Weather Station P were used to calculate oceanic CO₂ uptake. The subarctic North Pacific waters were shown to be a small net sink for CO₂. These observations are also being used to develop models of the ocean carbon system, in collaboration with scientists at UBC and the Swedish Meteorological Institute in Stockholm. Such models are required to predict the effect of possible national and international policy changes on future levels of climatologically active gases. (Contact: C.S. Wong)

Data from a series of ship-of-opportunity cruises crossing the Equator showed a large scale change in both nutrients and the amount of CO₂ given off during the weak 1986-87 El Niño event. The warm surface layer prevented upwelled nutrient- and CO₂-rich water from reaching the surface. (Contact: C.S. Wong)

The increase of amplitude of the seasonal cycle in atmospheric CO₂ was examined for evidence of biospheric enhancement of CO₂ uptake by land vegetation. Between 1971 and 1979 the amplitude of the seasonal cycle of atmospheric CO₂ at OWS 'P' grew by 1.4% annually, while no change was found at Alert in the high Arctic. A hypothesis that increased levels of atmospheric CO₂ increased winter season photosynthesis in the boreal forest was developed to explain the difference. (Contact: C.S. Wong)

Data Assessment

Science Review
1989/90

15

The Data Assessment Division facilitates access to scientific information and data and provides advice about the marine environmental impacts of industrial development. The Division is also involved in coordinating regional planning within the Science sector and is the sector's first point of contact for a number of clients, including DFO Habitat Management.

Climatology

Freshwater runoff was below normal in southern British Columbia throughout most of 1989. Sea surface temperature was above normal in the spring and summer months. At the Amphitrite Point light station, where the record of daily sea surface temperature readings goes back to 1934, the monthly average temperatures for April and May 1989 were the warmest ever.

Environmental Advice

The pace of hydrocarbon exploration in the Beaufort Sea is slowing down. Only four well proposals were reviewed during the year, and the outlook for 1990 is for a further decrease. The major issues for DFO during these reviews were the capability for "same season relief wells" and the adequacy of contingency planning for the unlikely eventuality of an accident during drilling. A "same season relief well" refers to the capability of an operator to drill a second well to regain control over a blowout before environmental conditions, such as breakup, impose a halt to all operations. (*Contact B.D. Smiley*)

The disposal of waste materials at sea is regulated by Environment Canada, through RODAC (Regional Ocean Dumping Advisory Committee), with advice from DFO. Applications are required for each proposed project, and most are for the disposal of dredged sediments removed from nearshore areas to improve navigation and industrial wharf operations. Forty-seven applications for ocean dumping on the Pacific Coast were assessed, reflecting a normal level of operations. Ten applications (21%) were rejected because contamination levels were beyond those allowed by regulation.

The procedures governing ocean dumping were modified during the year. New analytical requirements were introduced following the discovery of extensive dioxin and furan contamination around bleached kraft pulp mills and concern about the levels of polycyclic aromatic hydrocarbons in sediment adjacent to industrialized areas. In response to research into a phased system of testing, a requirement for sediment bioassays has been instituted for projects where organic contaminant concentrations are above a threshold level.

New procedures for assessing the adverse environmental effects of activities undertaken within Science were developed to comply with the federal government's Environmental Assessment and Review Guidelines Order. The potential environmental effects of each new or substantially modified scientific project must be approved prior to beginning the project. (*Contact R.C.H. Wilson*)

Effects of Pollution in B.C. Waters

A serious current pollution problem in B.C. coastal waters is due to polychlorinated dibenzodioxins and dibenzofurans (PCDD's and PCDF's). The major marine sources of these toxic chemicals are the outfalls of bleached kraft process pulp and paper mills.

Oxygen depletion in waters adjacent to some pulp mills is also a problem, particularly in Alberni Inlet and Neroutsos Inlet where pulp mill effluent causes severe oxygen depletion under stable oceanographic and meteorological conditions, resulting in conditions unsuitable for migrating salmon.

Benthic habitat is affected adversely by wood fibre lost from ten coastal pulp mills and mine tailings, the latter primarily at the site of a copper mine in Rupert Inlet. While recovery of benthos from the effects of wood fibre is thought to take many decades, it is known that recovery from the effects of mine tailings is much more rapid. For example, the benthos in Alice Arm recovered within a few years of closure of the mine at that location, although the makeup of the benthic communities was altered to species favouring soft-bottom substrates.

While the preceding paragraphs outline only some of the problems which exist in the Pacific marine environment, there are instances where changes in effluent treatment practices and discharge methods have resulted in the recovery of marine systems and water quality. As a result of improved sewage collection and treatment procedures, the waters surrounding Parksville/Qualicum on Vancouver Island have been reopened to shellfish harvesting and intertidal habitats around many coastal pulp mills have been improved. However, trend data for many problems is either missing or misleading and scientists are still uncovering new evidence of problems that may have been present for decades. Problem identification and efforts to understand and control the causes of pollution continue to be a high priority.
(*Contact: R.C.H. Wilson*)

Biological Sciences Branch

Science Review
1989/90

17

Salmon Production Research

Research programs in the Salmon Production section include stock assessments and information systems to provide advice for conservation and management of Canada's Pacific salmon resource, biological studies of Pacific salmon, development of computer software and analytical methods for fishery science, and studies of nutrient application to sockeye nursery lakes to increase the catch of sockeye.

Chinook and Coho Salmon

Researchers continued to determine the total fishing mortality on chinook salmon in southern B.C. seine fisheries, and conducted stock assessments of southern B.C. chinook and coho salmon. Investigations in the seine fishery have consistently demonstrated that DFO records of catch, which are based on the sale of fish, significantly underestimate the catch of small chinook salmon. Stock assessments provided the scientific basis for renegotiation of chinook catch levels specified in the Pacific Salmon Treaty, and identified the importance of Harrison River chinook to southern B.C. fisheries. (*Contact: P.J. Starr*)

Electrophoretic studies of protein variability between chinook populations in southern B.C. have revealed that many of these populations are genetically different. This study is conducted in collaboration with the Washington Department of Fisheries as part of a coastwide (California through Alaska) evaluation of genetic differences to identify chinook stocks harvested in mixed-stock fisheries. The degree of genetic difference between southern B.C. chinook populations is consistent with the geographic proximity of the stocks and differences in their biological characteristics (e.g. season of spawning migration, ages-at-maturity, ocean distribution). (*Contact: B.E. Riddell*)

Studies comparing hatchery and wild coho salmon have demonstrated differences in agonistic behaviour, genetic correlations between morphological and meristic traits, and in body morphology. Hatchery coho were more aggressive than wild coho when challenged with a mirror image of themselves. While this test environment is obviously artificial, results from the tests are consistent with challenge tests between pairs of fishes of equal size. Body morphology of juvenile coho varies with the rearing environment, however, rearing hatchery and wild coho in a hatchery environment demonstrated the existence of genetic differences as well. (*Contact: B.E. Riddell*)

Salmon Stock Information and Interpretation

Development of software for convenient data access, graphics and a finclip recovery database was completed. The latter was structured similar to the existing CWT (coded-wire tag) database. However, finclip data are more complex to process since relatively few finclip marks are possible and the same mark may be used in different contexts. Consequently, special care must be taken in associating releases and recoveries. A system was built to provide quick, flexible reports from the catch database. The data of interest can be selected according to a wide variety of criteria and the format can be defined by specifying the content of rows and columns. (Contacts: L. Lipt, M. Holmes)

An experiment continued to mark salmon through diets enriched in selected elements. The mass marking technique allows entire groups of hatchery-reared salmon to be marked and, based on elements in the diet, be distinguished from unmarked fish by chemical analysis of their scales. Preliminary evidence suggests that strontium and rubidium may be useful for marking chinook and coho salmon. Both elements are readily incorporated into the scale and cause no deleterious side effects. A model has been developed for predicting their retention in scales as fish grow. (Contact: T.J. Mulligan)

Research in 1989/90 led to publications documenting techniques for assessing fish growth, maturity, and survival; models for comparing measures of fish population abundance; and statistical methods for comparing maturity characteristics of different populations. These investigations emphasized quantifying uncertainty since management options can be greatly influenced by the statistical error inherent in collecting fishery data. (Contact: J. Schnute)

Lake Enrichment Research

Seasonal studies in the treated and control arms of Kennedy Lake continued to monitor the effects of changes in fertilizers and treatment strategies on food chain productivity. The "front-end loading" strategy (highest weekly nutrient enrichments in June with weekly loadings tapering off through September) used in Kennedy, Hobiton and Henderson lakes was highly successful at increasing and sustaining levels of grazeable phytoplankton for juvenile copepods and cladocerans in the spring and early summer. Relative to the control arm and previous treatment years, unprecedented increases of up to 20-fold in summer and fall densities of copepods and cladocerans were recorded. Sockeye presmolts from the treated arm responded to the increased zooplankton food with a 38% increase in mean length and a nearly three-fold increase in mean weight relative to fish from the control arm. Improved sockeye growth resulting from the change in treatment suggests that the productivity of sockeye food chains and the biological efficiency of lake fertilization can be significantly increased by tailoring treatment strategies to the seasonal population dynamics of the zooplankton

communities in treated nursery lakes. A total of seven lakes (Great Central, Henderson, Hobiton, Kennedy, Nimpkish, Woss and Long) were fertilized for 18 weeks with high concentration liquid fertilizers. (Contact: E. MacIsaac)

In continuing efforts to understand the role of picoplankton (0.2-2.0µm) and nano-flagellates in plankton foodwebs, electron microscopy (SEM/TEM) was used to examine the characteristics of microaggregates, ubiquitous particles in the euphotic zone of sockeye salmon nursery lakes. These microaggregates are epiphytic and endophytic associations of picoplankton with larger phytoplankton. They are frequently seen at times of severe nutrient limitation in late summer and early autumn. It is believed that these microaggregate particles are dynamic, living assemblages where photosynthesis, grazing, and nutrient regeneration are active. Aquatic ecologists consider them as an important intermediary in the transport of phytoplankton carbon to micro- and macro-zooplankton in both marine and lacustrine pelagic ecosystems. (Contact: J.G. Stockner)

Lake enrichment assessment and research is conducted to define coastal lake carrying capacities for sockeye production; assess links between sockeye freshwater production processes and variations in marine survival and; apply this knowledge to improve the basis for management of sockeye stocks on the British Columbia coast.

Studies continued concerning the range of conditions under which additions of nutrients may be used to increase the production of juvenile sockeye salmon. Enclosure studies and empirical data indicate that cropping pressure exerted by limnetic fish has a much greater impact on zooplankton communities of coastal B.C. lakes than invertebrate predators. In untreated coastal lakes, fish densities greater than 5 kg/ha generally dominate zooplankton production processes. Lake fertilization will buffer against such effects up to 10-15 kg/ha of limnetic fish. However, when limnetic fish communities exceed 10-15 kg/ha, production of sockeye prey organisms is likely to be uncoupled from "bottom-up" benefits of lake fertilization. There are exceptions to these generalizations, apparently the result of subtle differences in the way that single species of zooplankton may serve as either energy sources or sinks for juvenile sockeye. (Contact: K.D. Hyatt)

Fraser Lakes Research

The Fraser Lakes project investigates factors affecting growth and survival of juvenile sockeye salmon and the number of sockeye that can be produced in lakes of the Fraser River drainage. This research is essential for understanding the role of biological factors in the quadrennial cyclic production of sockeye salmon in this system. In addition, estimates of juvenile sockeye abundance are used to predict future run sizes of returning adult sockeye. Research efforts concentrated on Chilko, Shuswap and Quesnel lakes, all important producers of sockeye salmon.

Collaborative investigations were also carried out on Cultus, Fraser, and Pitt lakes. Several limnological and hydroacoustic surveys were carried out in Pitt Lake in an effort to better understand the lake's carrying capacity and the potential for increasing sockeye production in the lake. (Contact: K. Shortreed)

Sockeye Biology and Assessment

Smolt-to-adult survival increases with smolt size within Chilko Lake sockeye salmon smolt migrations. Within brood years the mean distance between the focus of the scale and the first annulus was greater for adult scales than smolt scales, indicating a higher survival for larger smolts. However, there was no significant relationship between smolt-to-adult survival and mean annual smolt fork length based on a 33 year time series. The abundance of smolts of different fork lengths, based on back calculation procedures from adult scales, was compared with the abundance of smolts of different fork lengths at the time of out-migration within brood years. Smolt-to-adult survival increased from approximately 5% for 76mm smolts to 14% for 87mm smolts. (Contact: M.A. Henderson)

A study was undertaken to determine the factors limiting the production of sockeye salmon from the Pitt Lake system (lower Fraser River) and to determine the carrying capacity of Pitt Lake for juvenile sockeye salmon. Pitt Lake sockeye have a higher growth rate in spring and summer and achieve a larger size by the end of the growing season than sockeye in four other Fraser systems examined. Analysis of hydroacoustic and trawl data indicates a large spatial and temporal overlap in the distribution of threespine stickleback, longfin smelt, and juvenile sockeye salmon in the pelagic zone of the lake. This establishes the basis for a potential competitive relationship. However, diet analysis of smelt and juvenile sockeye revealed that the diets did not overlap to a significant extent. Cladocerans were the principal prey of juvenile sockeye salmon while copepods were the dominant forage of longfin smelt. (Contact: M.A. Henderson)

Two distinct sockeye life history types may exist within the Pitt Lake system. Juveniles move down from the spawning tributary at the top end of the lake to rear in the littoral zone near the outlet of the lake. In early July, one group appears to migrate out of the lake into the estuary to rear while the remainder move off into the pelagic zone of the lake until the following spring. Gillnet sampling for predators indicates that predation by other fish may not be a major source of mortality for juvenile sockeye salmon in Pitt Lake. (Contact: M.A. Henderson)

Test fishing was carried out in Cultus Lake to evaluate methods for selectively removing adult squawfish from the lake. Since squawfish are effective predators of juvenile sockeye, it may be feasible to enhance the Cultus Lake sockeye population by the selective removal of adult squawfish. Serial hydroacoustic surveys were undertaken to monitor within-lake survival of juvenile sockeye from the 1988 brood year. Following enumeration of the sockeye smolt population in the spring of



Test fishing for adult squawfish in Cultus lake.

1990, selective squawfish removal by purse seining and live trapping on squawfish spawning beaches will begin in the summer of 1990.
(Contact: C.C. Wood)

A new technique for estimating stock composition, run-timing and escapement to the large river systems of the Nass, Skeena and Stikine was evaluated. Sockeye caught in river test fisheries and from known spawning populations were examined for parasite, age and biochemical genetic traits. Comparing the in-river test fishery samples to those of the spawning grounds in conjunction with actual counts of sockeye entering Meziadin, Babine and Tahltan lakes provides estimates of sockeye spawning numbers in the entire river system. Escapement estimates in 1989 were 115,000, 1,450,000, and 57,000 to the Nass, Skeena and Stikine rivers respectively. (Contact: D.T. Rutherford)

Sockeye enhancement opportunities in the Stikine and Taku rivers in northern B.C. have been investigated since 1987. Projects include collection of plankton samples in five lakes; collection and analysis of detailed physical and chemical water quality data at Tahltan Lake on the Stikine River, the first lake scheduled for fry stocking; sampling of wild sockeye smolts migrating from Tahltan Lake; and disease sampling of indigenous fish populations in two candidate lakes for stocking to provide information required by federal and provincial fish health authorities. (Contact: R.B. Morley)

Genetic studies have revealed that sockeye and kokanee (the non-anadromous form of sockeye) are reproductively isolated from one another, even when they spawn in the same stream at the same time. Since the forms are nearly identical physically, it is probable that they compete for food resources during their first year of life. To address this hypothesis, the relative abundance, distribution, size and diet overlap of sockeye and kokanee in Shuswap and Takla Lakes were compared. A genetic marker has been discovered which is used to distinguish juvenile sockeye and kokanee. Sockeye growth was more rapid than kokanee but there was considerable overlap in size between forms indicating the potential for dietary overlap and competition. Other studies on the age and size at maturity of sockeye and kokanee showed conclusively that age of maturation in sockeye is determined both by heritable (genetic) and environmental (growth rate) components. Females sired by kokanee males matured at a younger age and smaller size than those sired by sockeye males. Research into the genetic differentiation of sockeye and kokanee is continuing. (Contact: C.C. Wood)

Salmon Dynamics Research

The Salmon Dynamics Section investigates causes of recruitment variation in salmon and herring off the west coast of Vancouver Island, and conducts research in support of stock assessment and fisheries management for Pacific salmon and marine mammals. The section is also involved in high seas research studies to evaluate interception of Canadian salmonids in high seas fisheries.

La Perouse Bank Project

This program is evaluating the influence of oceanographic factors on fish predator-prey interactions on the continental shelf off southwestern Vancouver Island. Together with physical oceanographers from IOS, biologists from the Biological Sciences Branch (BSB) are studying the effect of changes in oceanic conditions and in the abundance of offshore predators on recruitment of Pacific herring, sablefish and Pacific cod.

An extensive trawl survey was conducted to determine the distributions and diets of the dominant fish species. A multispecies predator-prey model was developed using five years of diet information collected during the project. Herring and euphausiids are the principal prey in the model, while hake, dogfish and chinook salmon are the dominant predators. Preliminary results indicate that at current stock levels, hake, herring and dogfish eat some 360,000 t of euphausiids around La Perouse Bank between mid-June to mid-October. During the same period, hake, dogfish and chinook eat 35,000 t of herring, while dogfish consume 31,000 t of hake. An assemblage of subordinate predators eats an additional 25,000 t of herring annually. As a result of the trawl surveys, all annual natural mortality of the lower west coast of Vancouver Island herring stock can now be accounted for.

The predator-prey model confirms that hake is the dominant predator of herring, and that interannual variations in predation intensity are large enough to affect herring recruitment. The model also highlights the key role euphausiids play in supporting the migratory and resident fish stocks that feed in this very fertile region during the upwelling season. (*Contact: D.M. Ware*)

Coho Program

Stock assessment advice on Strait of Georgia and Fraser River coho stocks was provided and approved through PSARC (Pacific Stock Assessment Review Committee). In addition, program staff continue to provide technical advice on all coho issues to the Pacific Salmon Commission and Canadian negotiators.

(*Contact: R. Kadowaki*)

Much progress has been made in the development of instream indexing techniques utilizing counts of adult coho salmon in particular reaches of a stream to obtain accurate and precise estimates of the escapement to that stream. Escapement estimates using a stratified indexing design for Black and French Creeks were within 12% of independent mark recapture estimates for 1987, 1988 and 1989. A computer simulated index design using data from snorkel surveys also produced reasonably accurate escapement estimates for the Trent River. It appears that instream indexing techniques could potentially provide acceptable coho salmon escapement estimates.

Correlation of annual escapements of different stocks of coho salmon in a region through time has also been evaluated. While adult coho returns to French and Black Creeks have shown strong positive correlations, returns to the Trent have been relatively stable and not highly correlated with French and Black returns. This may be due to the fact that the Trent is a highly enhanced system. Total escapements to the Little Qualicum, Big Qualicum, Quinsam, Puntledge Rivers and Roy Creek, have not been highly correlated with each other, or with French, Black, and Trent escapements, which again may be due to the differential enhancement in these systems. (*Contact: J. R. Irvine*)

Coho Productivity Studies

Adult and juvenile coho were counted during spring and fall migrations at fences located on Mesachie Creek, a tributary of Cowichan Lake and the Lachmach River at the head of Work Channel near Prince Rupert.

The Lachmach River produces 20,000-25,000 smolts annually, a production rate approximately twice the norm for a southern stream of comparable size (8 km) and habitat diversity. The key to this higher productivity seems to be the abundance of old beaver pond habitat within the watershed.

Smolt production from Mesachie Creek has declined to 20% of the levels observed in the mid-1970s while escapements to the major Cowichan Lake spawning areas have declined to 50% of the levels observed in the early 1940s and mid 1970s. Poor marine survivals (2-3%), continued high fishery exploitation rates (>75%), and accelerating habitat loss have been factors in the decline. Habitat losses of major concern are the urbanization of the lower Cowichan River floodplain and estuary and dewatering of upper Cowichan Lake spawning areas. As coho migrate extensively in the Cowichan, it appears that the entire watershed must be viewed as an integrated production system rather than as a group of smaller production systems.

Work continued on examination of phenotypic variation in lake and creek rearing coho. Synoptic surveys of the Cowichan drainage and 15 drainages throughout B.C. confirmed that habitat-specific phenotypic differences were common in most areas. The phenotypic diversity is genetically based and is adaptive. (Contact: L.B. Holtby)

Coho Food Relations

Complete analysis of returns to catch and escapement of 17 groups of semi-naturally-reared coho salmon smolts from four brood years indicated that their survival was lower than or similar to the returns of conventionally-raised hatchery fish whose maximum survival to catch and escapement was 26%. A month's delay in release of the semi-natural fish did not increase returns, contrary to a current predictive model. (Contact: H. Mundie)

An experimental mesocosm, developed for determining the effects of inorganic enrichment of salmonid streams, has been used successfully for environmental assays of streams of contrasting water quality. (Contact: H. Mundie)

Coho Colonization

Coho smolt runs on three systems which received fry plants in 1988 were evaluated. Results were mixed, with survivals ranging from well below, to at par with, expectation.

Adult returns and CWT-information from 1987 plants indicate normal marine survival and exploitation rates. There is increasing evidence of unexpected complexity and variability in life history strategies employed by coho in fresh-water systems, which may challenge conventional notions about coho life history, their requirements, and ways and consequences of their enhancement. (Contact: R.A. Barns).

Ocean Salmon Program

Science Review
1989/90

25

Determination of marine survival of juvenile salmon during the early sea-life period was the main focus of this program in 1989. The three major activities were: (1) determining the abundance and distribution of juvenile sockeye, chinook, coho, and chum salmon in Alberni Inlet and Barkley Sound, (2) estimation of the mortality of juvenile salmon due to predation, (3) completion of the development of the new salmon beam trawl gear for the FRV W.E. RICKER.

Purse seine sampling of juvenile salmon was again restricted to Alberni Inlet and Barkley Sound. Between April 13 and July 14, a total of 193 purse seine sets were completed. As in previous years, catch-per-unit-effort (CPUE) values indicate that juvenile sockeye were the most abundant species of salmon in Barkley Sound, followed by chum, chinook, and coho salmon. Peak abundances of sockeye, chum, and coho occurred during the last week of May and first week of June, but the highest catches of juvenile chinook salmon occurred during the last two weeks of July. Chinook consistently utilize Barkley Sound as a rearing area to a much greater extent than sockeye, chum, and coho salmon. The peak abundance of juvenile sockeye in Barkley Sound was a factor of two times higher than in previous years, occurring about one month later than in 1988 and two weeks later than in 1987. The higher abundance resulted from the unusual occurrence of simultaneous migration of sockeye smolts out of both Great Central Lake and Sproat Lake. (Contact: N.B. Hargreaves)

To test the hypothesis that predation during the early sea-life period is a major source of salmon mortality, a floating gillnet was fished at night at fixed locations throughout the study area from April 21-July 14. In addition to the gillnet samples, a balloon trawl was fished for a total of 12 nights, at three week intervals, and hydroacoustic surveys were made at three-week intervals to obtain biomass estimates for determining the abundance and distribution of potential predators, particularly hake, pollock and spiny dogfish. The stomach contents of all potential predators captured (a total of 5,399) were examined for evidence of predation on juvenile salmon.

Pacific hake were again the most important predators of juvenile salmon in the study area in 1989. Preliminary estimates indicate that about 12 million juvenile sockeye (more than 50% of total production) and 7 million juvenile chinook salmon (75% of the total production from Robertson Creek Hatchery) may have been consumed by predators during the early sea-life period in Alberni Inlet and Barkley Sound in 1989. (Contact: N.B. Hargreaves)

The BERNARD-SIGMUND salmon trawls are a new type of paired-trawl gear designed to allow continuous sampling of juvenile salmon at the sea surface. This unique gear will significantly extend the existing capacity to sample juvenile salmon and other resource species in coastal B.C. waters and in the open waters of the North Pacific Ocean. In preparation for the first major scientific cruise using the beam trawls, a large "A" frame was installed across the stern of the W.E. RICKER to facilitate the launching and retrieval of the gear. (Contact: N.B. Hargreaves)

Pelagic Fisheries

A Pelagic Fisheries Unit was created to continue high seas salmon and squid studies initiated in 1986. The 1989 high seas survey to determine the interception rate of salmon by the Japanese commercial squid driftnet fleet along new July and August squid driftnet boundaries was conducted aboard the F/V ARCTIC HARVESTER, a chartered commercial trawler. The ARCTIC HARVESTER fished a research drift (gill) net along 43°N and 46°N latitudes. Due to warm sea surface temperatures no salmonids were caught during the six-week survey.

In response to a Canadian request to have observers on board squid driftnet vessels to monitor catch, the Japanese Squid Driftnet Fishery Association voluntarily agreed to accept observers on board their vessels. In preparation for the start of the squid driftnet season, staff worked with the U.S. and Japanese Governments to provide trained observers. The three nation observer program placed five Canadian, four American, and 22 Japanese observers aboard vessels for the July/August fishing period. An additional five American and ten Japanese observers were placed aboard vessels for the June to December period. The observer data summary for July and August was completed in February, 1990, while the data summary for June to December was scheduled for completion on June 30, 1990. (Contact: S.M. McKinnell).

Recreational Fisheries

A project to provide an estimate of the number of chinook salmon released in the Georgia Strait recreational fishery as a result of the new (62 cm fork length) size limit was conducted. Four commercial trolling vessels were chartered to catch and measure chinook salmon for several days each month (April - September) in areas where most of the recreational chinook catch is taken.

A video tape showing the correct way to catch and release salmon in the recreational fishery was produced in conjunction with Fisheries and Communications Branches. The video has been widely circulated. (Contact: T. Gjernes).

Marine Survival of Salmon (M.A.S.S.)

The M.A.S.S. program is examining the effect of ocean conditions on the distribution and dispersal of sockeye, coho, and chinook salmon as well as migratory and feeding behaviour, and vulnerability of salmon to predation. The program is a collaborative one, involving scientists from BSB and Physical and Chemical Sciences and is carried out in Barkley Sound and off the southwest coast of Vancouver Island. Special emphasis is given to sockeye stocks from Alberni Inlet.

The distribution of immature chinook and coho over the banks off southwestern Vancouver Island in May was surveyed. Distribution patterns of both species were similar to those observed in other years.

with larger chinook most abundant in the more northerly part of the study area and smaller chinook most abundant in the south. Coho tended to be more evenly distributed but with highest catches on Swiftsure Bank. Whereas chinook were concentrated near the bottom, coho were concentrated in near surface waters. Catch rates for chinook averaged 8.5/hr and 3.8/hr for coho.

On the basis of this research it was concluded that concentrations of chinook and coho occurred in particular locations over the banks off southwest Vancouver Island but that the patterns of aggregation differ between species and among size classes within a species. It is not apparent from the data collected thus far that these aggregations are related to any particular ocean condition or to feeding success. The densities of immature salmon over the banks are relatively high, suggesting that these banks constitute important nursery areas for both species. However, juveniles from the nearby Robertson Creek and Nitinat River hatcheries were not found on these banks.

Results of laboratory experiments to determine the willingness of different salmon species to risk predation to obtain food and to determine the relative vulnerability of salmon to predation, suggest that chinook and coho would deal with the problems of obtaining food and avoiding predators in different ways and that their "strategy" should be revealed by patterns of variation in survival and growth rate.
(Contact: J. F. Morris).

Harbour Seals and Sea Lions

Sea Lions

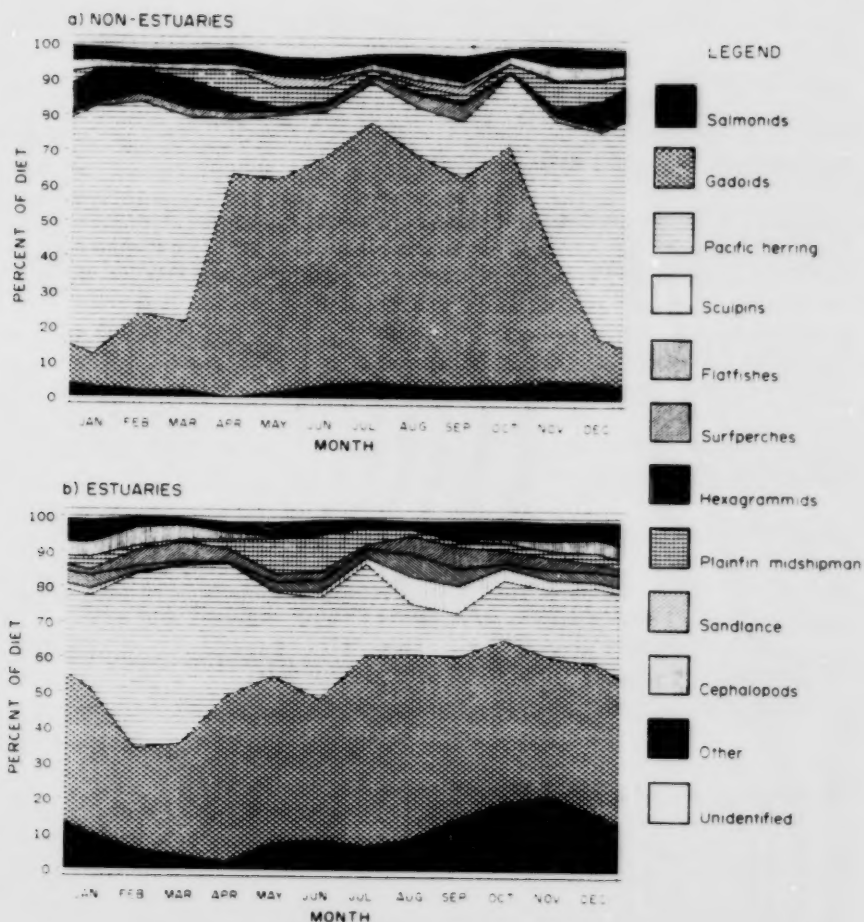
Aerial and boat censuses to monitor trends in the abundance of Steller and California sea lions wintering off southern Vancouver Island continued. In February 1990, 1,749 Steller and 2,490 California sea lions were counted in this area. (Contact: P. Olesiuk)

Harbour Seals

Research into the population trends and impact of harbour seals on fish stocks continued to be the highest priority in the marine mammal program.

Aerial censuses indicate that populations of harbour seals throughout British Columbia have been increasing at a rate of 12.5% per annum since the species was protected in 1970. Total abundance in British Columbia is estimated to have increased from 9,000-10,500 in 1970 to about 84,000-100,000 in 1989. The recent increases represent recovery of populations that had been maintained below natural levels by bounty kills from 1913-1964 and further depleted by commercial harvests for pelts between 1963-69.

Analysis of scats collected in the Strait of Georgia indicated that the diet was predominated by codfishes (mainly hake) from April-November



Diet of harbour seals in the Strait of Georgia.

and herring from December-March. Salmon were an important prey in the fall, especially in estuaries. A bioenergetics model incorporating data on the abundance, distribution, energetics, diet, and sex-and-age structure was developed to estimate annual prey consumption. Annual consumption in the Strait of Georgia in 1988 (15,810 seals) was estimated at 9,895 t, which was comprised of 4,214 t of hake (3.5% of the total stock), 3,206 t of herring (3.2% of the total stock), 394 t of salmonids (2.8% of total escapement), and the remainder of a wide variety of different prey. (Contact: P. Olesiuk)

Salmon Biology

Variation in scale patterns of juvenile chinook salmon rearing in 15 tributaries of the Yukon River was investigated, with considerable variation in circulus number observed among populations. Juveniles sampled in May lacked an annulus. Juveniles sampled in May and August/September had only about two thirds of the number of circuli

in the first freshwater zone found in returning adults perhaps indicating size-selective mortality among the juveniles. (Contact: C.B. Murray)

Genetic variation in resistance to thermal stress was compared for two British Columbia chinook salmon populations. Mortality rate in the southern Robertson Creek population was less than 10% after 10 days of rearing at 22°C, as compared to 60% in the northern Bear River (Skeena River tributary) after three days of rearing at 20°C. (Contact: T.D. Beacham)

An attempt to accelerate the maturity of Chilliwack River pink salmon to produce sexually mature salmon was initiated, using photoperiod and temperature controls, as well as the administration of somatotropins. If the project is successful, these mature fish will form the nucleus of a project to develop runs of pink salmon in the Fraser River in even years. (Contact: T.D. Beacham)

Genetic variation in resistance to vibriosis, furunculosis, and bacterial kidney disease was investigated in chinook, coho, and chum salmon. Family survival rates after exposure to the pathogens were correlated, although heritability of survival rates and time-to-death was low. (Contact: T.D. Beacham)

Salmon Habitat Research

Salmon habitat research is conducted to determine the productivity of freshwater, estuarine and marine habitats for salmon stock and habitat management as well as habitat restoration. Research data are provided on the impact of industrial activity including forestry, transportation, wastewater discharge, hydroelectric generation, and agriculture on the capacity of the regional habitat base to produce salmon. Projects are conducted to define the utilization of habitats by fish and the dependence of fish stocks on specific habitat types.

Habitat Quality

A cooperative (government, industry, public) research program focused on the effects of a new chemical (TCMTB) now being used as an anti-sapstain treatment for lumber. This compound proved to be highly toxic to juvenile Pacific salmon, killing 50% over 96 hours at concentrations between 5 and 16 parts per billion, depending upon the species and test medium (salt or fresh water). Numerous sublethal effects were recorded at concentrations down to 3 ppb, effects which are considered to jeopardize survival under natural conditions. Such effects included a three to nine-fold reduction in swimming speed, increased susceptibility to predation, loss of equilibrium, abnormal surfacing behaviour, inability to maintain position in currents, increased "coughing" frequency, abnormal responses to hypoxic conditions, decreased cover-response times, gill damage, impairment of respiration and reduction in ability to accommodate transfer to salt water. Research to determine the appro-

priateness of the level (15 parts per billion TCMTB) which lumber treatment operations are currently permitted to discharge, is continuing. (Contact: I.K. Birtwell)

Marine Pollution and Reviews

BSB representation on the Regional Ocean Dumping Advisory Committee continued. Forty-seven applications for ocean dumping were reviewed under Part VI of the Canadian Environmental Protection Act.

Assistance was provided in preparation of Chapters Five: "Oceans and Coastlines" and Six: "Fisheries" for the 1991 State of the Environment Report. A number of information sheets were prepared as background information. Topics included: sewage and urban/agricultural runoff, industrial effluents and dumping, competing uses of estuaries/wetlands, accidental spills, dams and diversions, introduction of exotic species, and natural toxins. (Contact: M. Waldichuk)

Fish/Forestry

The results of a synoptic survey of coastal B.C. streams initiated to examine the relationship between watershed cut history, physical condition of the stream channel and salmonid population status, indicate that after timber harvest there is a decline in the percentage of two year old coho in the fish community and the size of fish increases after harvest. Following regrowth these trends do not return to old growth status. (Contact: J.S. Macdonald)

Surveys of interior watersheds have been initiated to begin establishing an interior fishery-forestry interaction project. Data bases have been developed from collections in northern and southern Thompson River tributaries and site investigations have taken place in northern Fraser River watersheds (Bowron, Stuart-Takla). In addition, physical and biological studies initiated during logging in the Slim Creek/Tumuch Lake watershed between 1971 and 1975 are being repeated. The data collected will allow comparisons between these variables as they existed in the early 1970s. Of particular interest are sediment loads, insect production and salmonid community structure. (Contact: J.S. Macdonald)

Fitness and Sensitivity

Four bleached kraft pulp mills discharge bio-treated effluents to the upper Fraser River. The effluents discharged by these mills usually meet acute detoxification criteria specified by Federal Regulations and Provincial Objectives. Although unproven, it has been presumed that these criteria provide a safe environment for aquatic life, in particular the large numbers of Pacific salmon found in the Fraser River. However, chemical assays reveal residual organochlorines, including dibenzo furans and dibenzo dioxins, in the effluents. Total organic chlorine

(TOCL) levels averaged 3.3 kg/ADT in bio-treated effluents. Juvenile chinook collected from the Fraser River contained chloro-organics of bleached kraft mill origin (chloroguaiacols, chlorophenols, furans and dioxins) while extractable organic chlorine (EOCL) and mixed function oxidase (MFO) enzymes were elevated.

Although the biological implications of these findings for chinook salmon are known, there is concern that contaminant residues and elevated MFO levels are compromising chinook salmon survival. To investigate this, juvenile chinook were exposed to bio-treated bleached kraft mill effluent (BKME) at concentrations and temperatures representative of the upper Fraser in winter and spring.

Fingerling chinook bioconcentrated chlorophenols, chloroguaiacols, furans and dioxins in proportion to effluent concentrations. Dioxin and furan levels were much lower in experimental fish than in fish collected from the Fraser River, suggesting that bioconcentration of dioxins and furans in wild fish was primarily via the food chain. EOCL levels were in proportion to effluent levels and were similar to those measured among fingerlings sampled from the river. Chlorophenols, chloroguaiacols, dioxins and furans accounted for less than 1% of the EOCL body burden.

Preliminary conclusions indicate that exposure to non-lethal bio-treated BKME at environmental concentrations and temperatures led to contaminant burdens accompanied by biochemical and histological responses. However, the low body burdens of dioxins and furans compared to wild fingerling chinook indicated that the laboratory environment did not fully simulate the natural environment. Laboratory exposures did not compromise freshwater growth, seawater acclimation or subsequent growth in seawater. (Contact: J.A. Serviz)

Chinook Salmon/Freshwater Habitat Quantification

A second winter of investigating the habitat requirements of chinook salmon in the Nechako River indicated that juvenile fish were distributed throughout the entire river from Cheslatta Falls to Prince George and were equally abundant in upper and lower reaches of the river. There was no noticeable decline in their abundance over the winter. During the day, the fish appear to bury into the substrate emerging in darkness and coming close to shore. At night they were often observed resting on or near the bottom in water 45 cm deep. The fish chose positions about two m from shore and because these were often in slow water (<5 cm.s⁻¹), the substrate was usually covered in silt. Future winter studies are planned to support a major effort to design mitigation techniques to cope with further water withdrawal from the Nechako River. (Contacts: C.D. Levings, C.S. Shrivell)

To better understand changes in juvenile chinook habitat as a result of flow reduction, measurements of habitat conditions were made at three streamflows in Kloiya Creek. Results of this work indicated that the

area of the stream with suitable depth and velocity for juvenile chinook varied with changes in streamflow. The area of suitable habitat was greatest at low to medium streamflows (0.5-1.2 cm.s-1), but declined at higher streamflows (8.5 cm.s-1). Suitable area was greatest at streamflows near 30% of the mean seasonal flow which normally occurs during the spring. The area of suitable habitat measured eight cm above the streambed was much greater than at 6/10 of the depth, the location normally measured for assessment of fish habitat models. Equally important for habitat modelling was the different way that habitat at these two locations changed with reductions in streamflow. (Contact: C.S. Shirvell)

A review of six habitat models using habitat measurements revealed that the models give good predictions of fish abundance at the original location for which they were developed (50%-96% accurate), but gave much less accurate predictions at new locations (7%-30% accurate). It does not appear that existing habitat models could easily be transferred to the Nechako River or Kloiya Creek without some adjustments. (Contact: C.S. Shirvell)

Estuarine and Foreshore Habitat

Analysis of tag returns from experimental releases of juvenile chinook salmon to the Campbell River Estuary indicated that the survival of chinook released to the estuary in 1985 was significantly higher relative to those released in 1983 and 1984. The 1985 fish showed no significant differences in survival between fish released into river, estuary, transition and marine habitats. Preliminary results of sampling with emergent traps on islands created in the estuary indicate that the developed habitats are functioning as food production sites for juvenile salmonids. (Contacts: C.D. Levings, C.D. McAllister)

In Fraser River Estuary studies, analysis of the distribution and feeding of juvenile salmon caught in the 1988 surface trawling program at Port Mann showed major differences between and within species. Whereas chinook fry were more abundant at stations closer to the south bank, more chinook smolts were found further offshore. Sockeye smolts were the most abundant fish in the surveys (other than eulachon). Examination of stomach contents of chinook smolts showed that they were feeding on adult chironomids at all sites, suggesting that the food produced in the "ribbon marshes" of the river is used in mid-channel habitats as well as the nearshore zone.

Preliminary results of sampling conducted at 1.5 ha of fish habitat developed at Mitchell Island showed that significant numbers of chironomids were emerging at the site, possibly in association with algal mats as well as vegetation. The peak of emergence appeared to be in May. Juvenile salmonids were also caught in the developed area. (Contact: C.D. Levings)

Aquaculture and Environment

A review document comparing the status of knowledge of interactions between salmon netpen rearing and wild fish habitat in coastal B.C. was prepared. (Contact: C.D. Levings)

Science Review
1989/90

33

Groundfish Research

The objective of groundfish research at PBS is to provide the scientific basis for rational management of approximately 60 stocks of fish and communicate this information to fishery managers, clients and the scientific community. Research is designed to determine the maximum (or optimal) yield from each species, a four-step process: identification of individual stocks within species; determination of annual and seasonal abundance and production; determination of biological properties such as growth, longevity, natural and fishing mortality rates, fecundity and life history; and development of mathematical models incorporating these parameters which can simulate the response of a stock to fishing and non-fishing environmental factors.

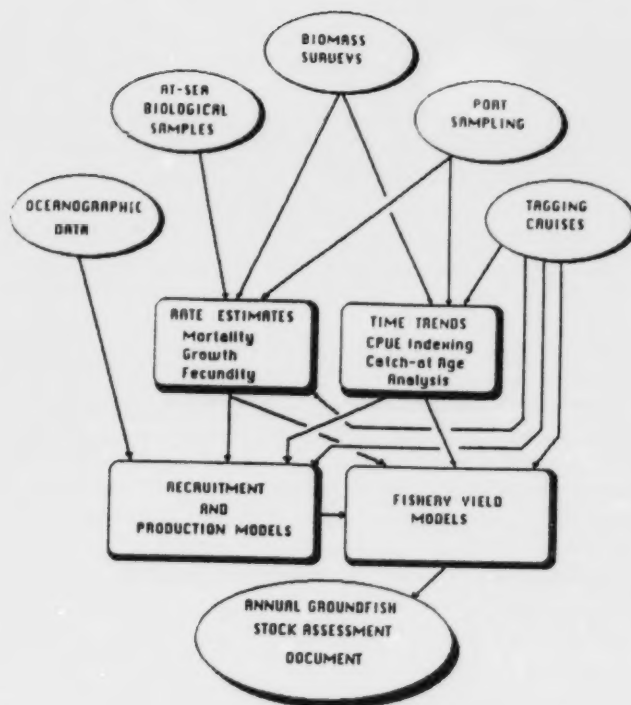
Stock Assessment

Groundfish assessments begin each spring using a multi-year data base for fishery statistics and biological research. A variety of assessment models are used including catch/age sequential analysis, age-independent surplus production, yield-per-recruit and linear models. Following completion of assessments in August, they are reviewed by the PSARC and recommended yield options sent to fisheries management staff.

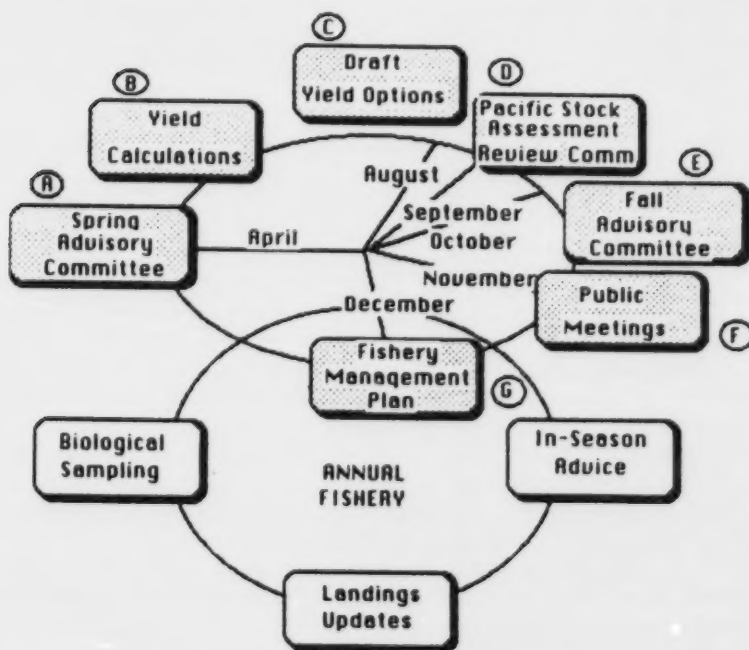
Following meetings with fishery managers in early October, a management plan is finalized and presented first to the Pacific Groundfish Advisory Committee (government and industry) and then to industry advisory meetings. (Contact: J.C. Rice)

Statistics and Sampling

Maintenance of the catch and effort database for the trawl and trap fisheries was the principal activity. Logbook records were merged with sales slip information. Biological data on the catch (length frequency, sex, age structures, gonad condition, etc.) were collected by sampling the various species landed. Development of an interactive database entry system for logbooks was completed and the system put into operation. An interactive system to add sales slip information to logbook information was also developed. An advanced version of the computerized measuring board that allows data to be directly dumped to a microcomputer was developed for use by port samplers in 1990.



Sources of information and methodologies used to determine groundfish stock assessments.



Annual cycle for groundfish stock assessment proceedings

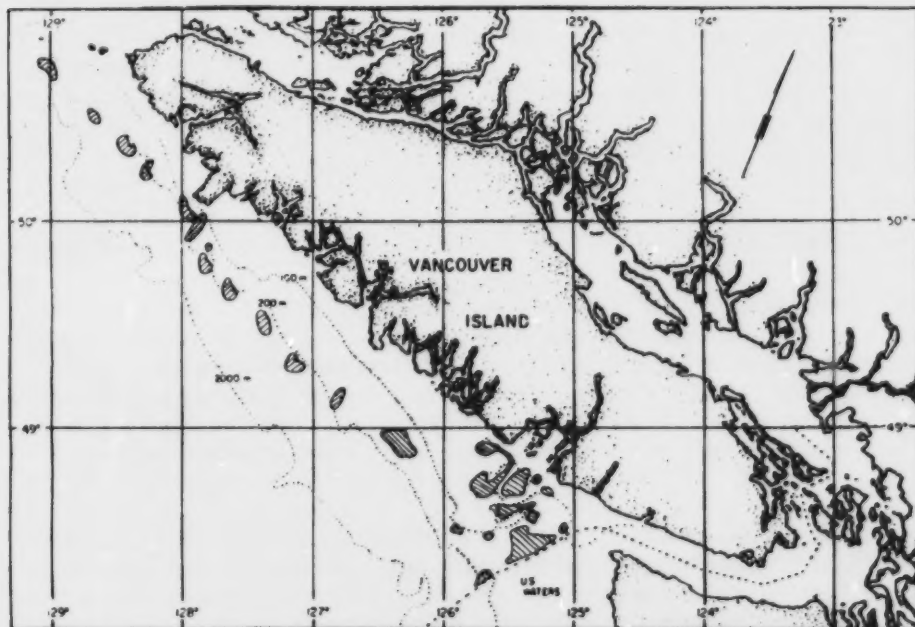
An analysis conducted on optimizing sample size versus sample number indicated that, for generating catch-at-age estimates, sample sizes of 50-100 were optimal when used in conjunction with otoliths or other age determination structures. (Contact: R.D. Stanley)

Pacific Hake

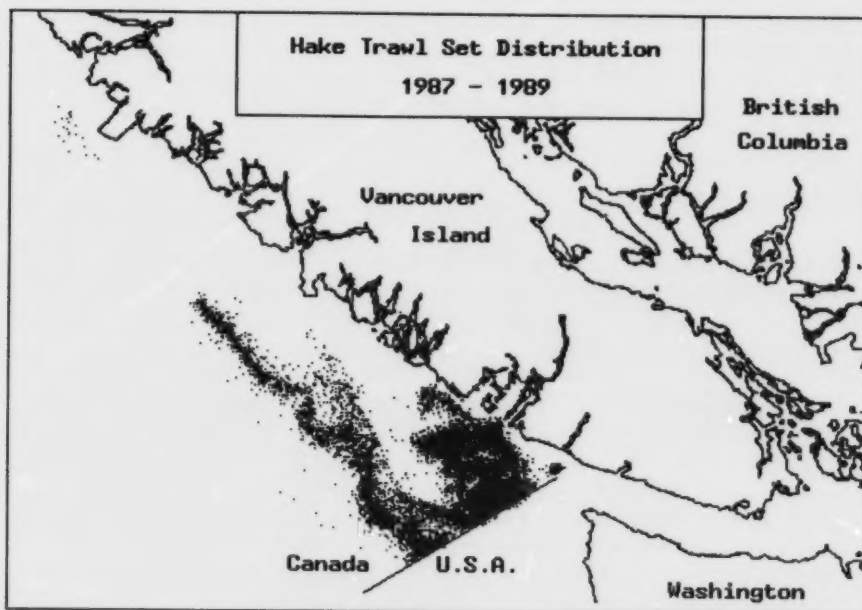
Monitoring and biological sampling of the offshore fishery continued with an extensive observer program. Observers provide independent estimates of catch and species composition for virtually all tows made in the course of this fishery.

A species-interaction trawl survey of offshore Pacific hake in the Canadian zone was conducted in August. This survey has been conducted annually since 1985, and is part of the longer term La Perouse Project. Considerable progress was made in implementing a computerized geographic information system (GIS) to aid in the examination of hake distribution in relation to oceanographic features. In addition, a hydroacoustic survey of offshore hake biomass was conducted in the La Perouse region of the Vancouver Area to examine the northern extent of the hake summer distribution. Hake were found along the 200 m contour extending into Queen Charlotte Sound. (Contact: G.A. McFarlane)

A survey to determine the distribution of spawning offshore hake conducted in February, located two large concentrations of spawning hake 100 and 150 nautical miles southwest of San Francisco. The length frequencies of the two schools closely resemble the fish found in the adjacent near-shore areas during the summer.



Coastwide distribution of hake based on the 1989 hake/herring echogram survey.



Hake trawl set distribution off the west coast of Vancouver Island, 1987-1989

Results of a study examining the causes of a general decline in size-at-age of offshore hake indicated that both selective fishing and oceanographic features contributed to this decline.

Another study to assess between-year variation in growth in Strait of Georgia hake and population productivity for this stock concluded that the influence of changes in growth rates on population productivity was small because of the relatively long generation time.

(Contact: G.A. McFarlane)

Sablefish

Biological and oceanographic data, collected as part of the La Perouse Project, were used to examine the biotic and abiotic factors influencing year-class success. A theory for year-class success incorporating abrupt changes in ocean productivity which occur during major climate events (change from a period of cooling to a period of warming) was proposed and the relevance of this theory to fisheries management examined.

A study examining the effects of an external tag on growth of sablefish and consequences to mortality and age at maturity was completed. Tagging reduced growth, increased mortality, and increased the age and size at 50% maturity. This could result in errors in the estimation of biological parameters obtained from tagging studies.

(Contact: G.A. McFarlane)

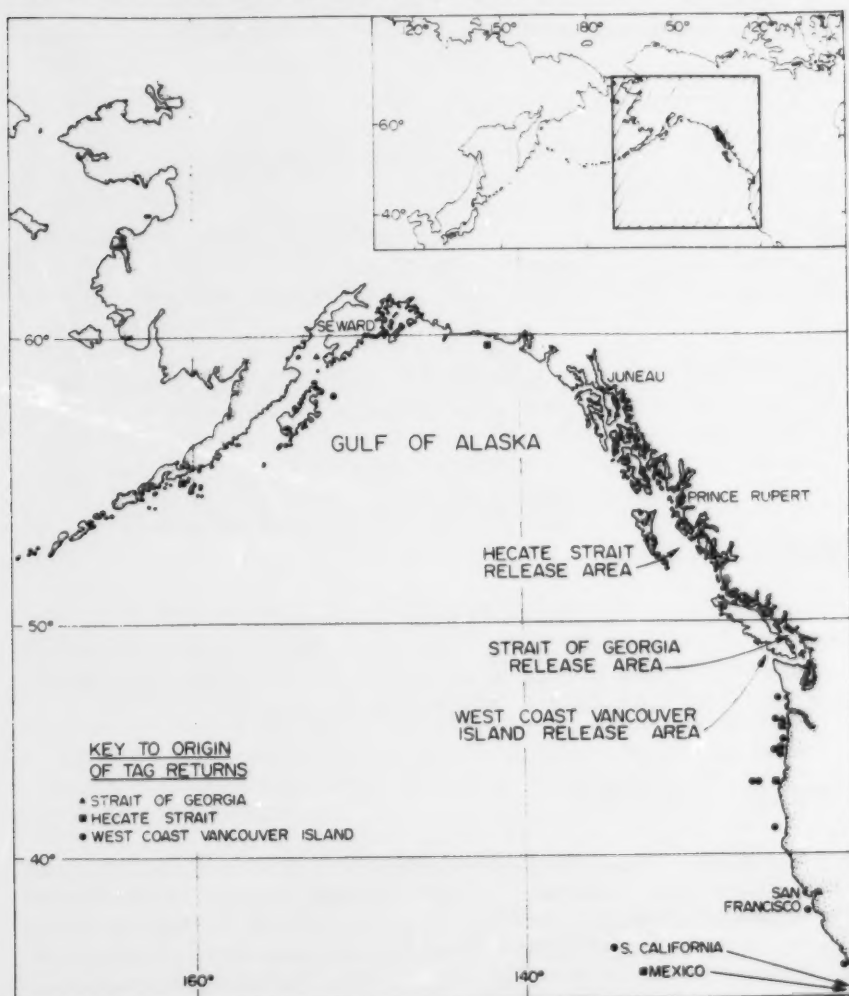
Spiny Dogfish

Science Review
1989/90

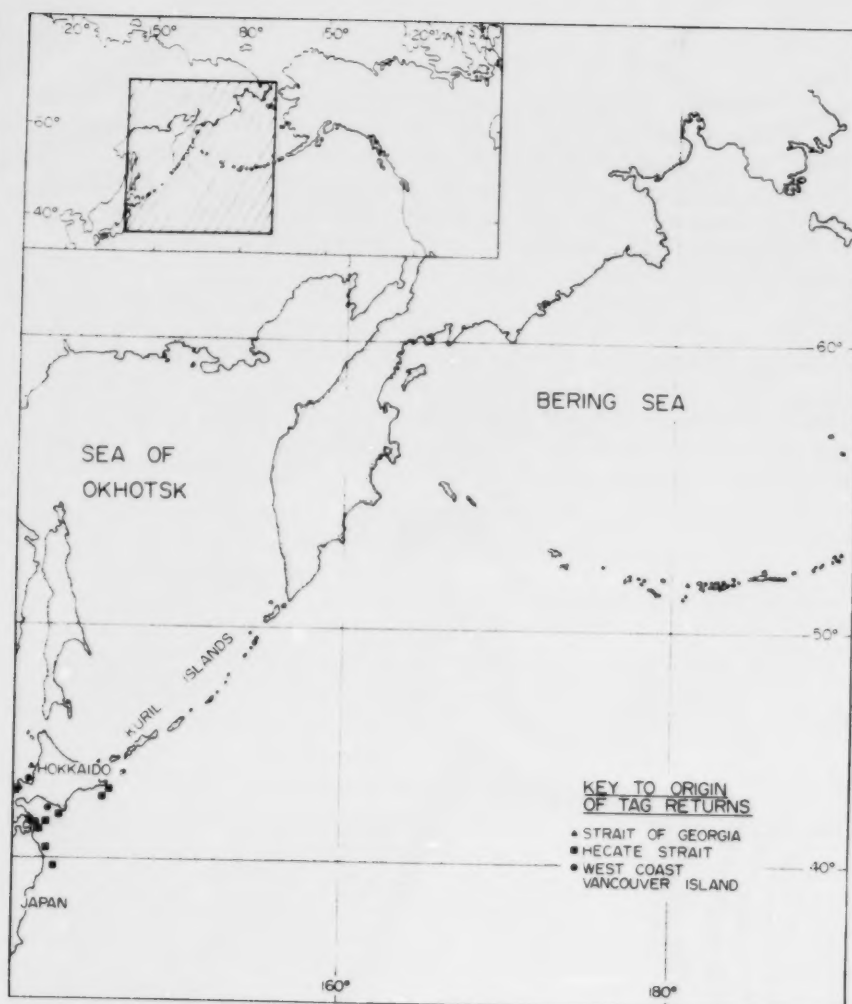
37

Approximately 2000 spiny dogfish were tagged in the Strait of Georgia in experiments designed to measure exchange between the Strait of Georgia and offshore stocks. Preliminary results indicate that exchange between the inshore and offshore areas may be greater than previously believed. Fish tagged offshore are highly migratory with recaptures verified from as far south as California, as far north as the Gulf of Alaska, and as far west as Japan.

A longline survey of dogfish abundance in the Strait of Georgia portion of the Vancouver Area was conducted in October. The survey was first conducted in 1986 and will be carried out every three years, in an attempt to monitor long-term changes in dogfish abundance and provide a reference time series to check against the current age-structured model used to assess dogfish populations. (Contact: M.W. Saunders)



Recapture locations of Spiny dogfish tagged in Canadian waters from 1978 to 1988 and recovered outside Canadian waters. (see next page)

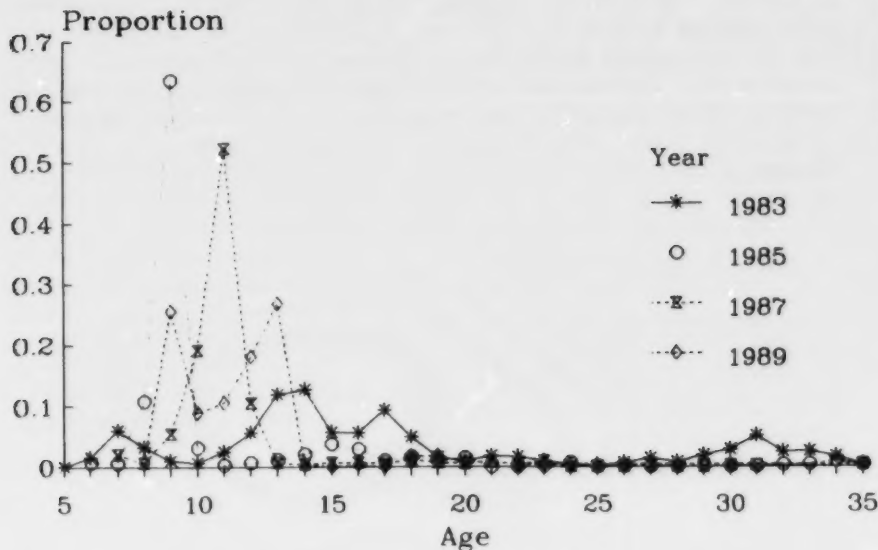


Walleye Pollock

An examination of age structures from five stocks in the Northeast Pacific Ocean indicated that the most appropriate structure or method varies among stocks. In general, the burnt otolith section consistently produced older age estimates. (Contact: M.W. Saunders)

Offshore Rockfish

A synoptic sampling cruise for slope rockfishes, primarily Pacific ocean perch (*Sebastes alutus*), was conducted in July. Length, maturity and age samples of over 7800 rockfishes, from southwest Vancouver Is. to Dixon Entrance, were collected. Sampling also included 816 sets of gill rakers for stock delineation of *S. alutus*, using the copepod parasite *Neobrachiella robusta*. These samples will be combined with others to examine the seasonal stability of stock-specific differences detected



Langara experimental fishery (Pacific ocean perch).

previously. The 1976 cohort of Pacific ocean perch continues to recruit in strength in the Moresby Gully area of Hecate Strait, but has been severely reduced by the experimental open fishery in the Langara Spit (Dixon Entrance) area.

Preliminary screening of yellowtail rockfish (*S. flavidus*) samples for parasites suitable as natural tags in stock delineation studies was completed. Two copepods from the branchial and nasal cavities, a monogenean from the nasal cavity, and myxosporidians from the gall bladder were identified as promising natural tags. In addition, five species of parasites were recorded for yellowtail rockfish for the first time.

A review of life history strategies and the impact of the unique features of rockfish life histories on their management concluded that indices of stock status much more sensitive than CPUE, such as reproductive value, must be employed if the roles of life span and cohort strength variation in the management of *Sebastes* stocks are to be understood. These other indices have merit due to their linear response to stock changes, compared with the asymptotic behaviour of CPUE.

(Contact: B.M. Leaman)

An examination of rockfish sampling procedures indicated that among-sample variance dominated within-sample variance. Sampling programs for catch-at-age information should therefore maximize the number of samples obtained, at the expense of obtaining larger sample size. Sample sizes of less than 100 were more efficient, and could even be less than 50, if greater numbers of samples were collected.

(Contact: R.D. Stanley)

Rockfish communities from trawlable and untrawlable habitats off the northwest coast of Vancouver Island were studied using sunken gill nets. Rockfish schools from the two areas differ in their diel behaviour and therefore can be distinguished acoustically. The catch from the trawlable area was dominated by Pacific ocean perch and splitnose rockfish, while sharpchin rockfish and red-banded rockfish dominated the catch at similar depths (near 200 m) from the untrawlable area. (Contact: L.J. Richards)

Inshore Rockfish

A method for determining the relationship between fecundity and another fish attribute, such as size or age, was developed. Data for quillback and copper rockfish were used for illustration. Simple linear and logarithmic models could not adequately describe fecundity-length relationships for these species, justifying the extra complexity of the new model. (Contact: L.J. Richards)

Lingcod

Lingcod abundance in the Strait of Georgia has been declining since the 1940's. A research program to develop rebuilding strategies for this stock was initiated in 1989. Results of a larval purse seine survey conducted in May indicated that larval densities had decreased since earlier surveys conducted in 1980-81. A SCUBA survey of nest-guarding male lingcod in early 1990 found no nests at the site of a 1978 survey, although nests were recorded at another nearby site.

Growth, dispersal, and mortality rates were estimated using 1982-1987 mark-recovery data. Lingcod tend to remain within 30 km of the release site one year after tagging. Male lingcod grow more slowly than female lingcod, and growth rates are less in the Strait of Georgia than off southwest Vancouver Island. (Contact: L.J. Richards)

Pacific Cod

In a study of maturity stages in relation to oocyte development, histological sections were prepared from samples collected during a previous research cruise. Further samples were processed for oocyte size distributions. After spawning, recovering fish have a single mode of oocytes 2-100 microns in diameter. By summer, some of these oocytes have increased in size so that a second mode is evident. This mode increases in size until February, when eggs are released at 1.0-1.1 mm.

The ovarian histology of Pacific cod was described and related to the spawning cycle. Relating exterior appearance to the histological features and oocyte growth helped to confirm that Pacific cod spawn once each year in February and March.

A maximum-likelihood technique was used to describe the timing of spawning activity of Pacific cod in the major regions of B.C. Dates of 50% completion of spawning for females by area were: March 4 for Strait of Georgia, March 9 for the west coast of Vancouver Island, February 22 for southern Hecate Strait and March 17 for northern Hecate Strait.

With the development of a new stock assessment model for the largest stock (Hecate Strait), it is now possible to set annual quotas. Until now, fishery managers have depended on fishing effort falling off for economic reasons to protect the stock from over-exploitation. It is estimated that a minimum stock size of one-quarter the historic mean biomass is necessary to maximize recruitment rate. The available potential yield is the estimated biomass of adults above this minimum level. The annual quota will vary widely with variation in recruitment. At present levels of effort, the quota is not being achieved by the fishery. (Contact: A.V. Tyler)

Flatfish

A study of the reproductive biology of English sole was completed. Over a two year period, ovaries were obtained from English sole in Hecate Strait for histological examination of the reproductive cycle. Peak spawning occurred between the first of September and mid-October, although the spawning period appeared to be somewhat protracted. Histological sections indicated stage-2 (recovering) oocytes were present during the months of January, February, March, May, October and November. Stage 3 (developing) oocytes were present in June, and stage 4 (gravid) oocytes were present in August. (Contact: J. Fargo)

Hagfish

An experimental hagfish fishery on the west coast of Vancouver Island continued. In the first year of collection of biological data, catch, CPUE and length frequency data were collected from all vessels participating in the fishery. Further work is required before recommendations concerning hagfish stocks and effects of the fishery can be made. (Contact: C.E. Neville)

Hydroacoustics

Acoustic species recognition techniques were developed. Based on variables defined by echo integration data, rockfish assemblages were classified into habitat categories with up to 97% success.

A study of the distribution and behaviour of rockfishes was initiated with a cruise in March, 1990. Traditional and acoustic methods were used to obtain complementary data especially for those fish close to the bottom or near steep slopes. Diel observations of fish distribution and biomass showed interesting patterns, which will be used in the long-

term assessment and validation of trawl surveys. While hydroacoustic estimates of the distribution and biomass of Pacific hake off Vancouver Island showed distribution patterns similar to those found in 1983, a reduced biomass was found in the area.

Hydroacoustic data were displayed and analyzed with a standard PC based image processing system which produced enhanced echogram-like images and will be able to recognize fish schools. This will lead to a better use of the information contained in fisheries acoustic data.
(Contact: R. Kieser)

Strait of Georgia Program

In the second year of a study to examine predation and its effects on the early marine survival of salmon smolts leaving the Big Qualicum hatchery, spiny dogfish was the predominant predator species caught in the study area. More juvenile herring were found in the stomach contents of dogfish than during the previous year. Adult salmon meat was found in dogfish stomachs at periods throughout the year. Pacific hake caught off the Big Qualicum River in July were identified as another potential predator of salmon smolts. (Contact: B.L. Thomson)

Hecate Strait

Analysis summarizing the distribution and abundance of 14 major species in Hecate Strait was completed. Species were placed into three categories, according to the degree of variability in their distributions:

<u>Species</u>	<u>Distribution type</u>
Arrowtooth flounder Pacific sanddab, Petrale sole, spiny dogfish	Stable
Big skate, Dover sole, English sole, Pacific halibut, rex sole, rock sole	Moderately variable
Pacific cod, Pacific ocean perch ratfish, sablefish	Highly variable

Species with stable distributions are considered to be likely candidates for abundance monitoring, while species with moderately and highly variable distributions are considered to be possible and unlikely candidates, respectively. Estimates of standing crop calculated from survey data indicate that the most abundant species in summer were arrowtooth flounder and spiny dogfish, while big skate, ratfish, and English sole predominated in winter. Major species abundance trends between 1984 and 1987 were as follows:

Species

Abundance trend

Science Review
1989/90

Arrowtooth flounder, big skate

Stable

Dover sole, rex sole

Increasing

Ratfish, rock sole, spiny dogfish,
English sole, Pacific halibut,
Pacific sanddab, Petrale sole

Decreasing

43

(Contact: A.V. Tyler)

Sablefish and Halibut Mariculture

Results of research conducted to date indicate that culture of both sablefish and halibut is biologically feasible. The development of new upwelling cone incubators for egg and larval rearing of marine species this year was a major breakthrough. The problems encountered last year due to physical stress appear to have been alleviated using this new system. Large numbers of larvae were successfully brought through the yolk sac and early post-sac larval period and into the flexion stage. (Contact: G.A. McFarlane)

Fish Age Determination

The Fish Ageing Lab aged approximately 14,000 groundfish (sablefish, Pacific hake, rockfish, lingcod, flatfish, pollock and Pacific cod) and 40,800 Pacific herring. Some 30,500 scales and otoliths were used to age a total of 12,000 salmon (chinook, coho, sockeye, chum and kokanee).

The lab continued to maintain and form new local, national and international contacts with other agencies involved in fish ageing. A member of the Jiangsu Marine Fisheries Institute arrived in February, 1990 to spend a year learning fish ageing methods and carry out research.

Pacific cod age structure studies indicated that fin rays provide more detailed biological information than the length frequency method. Similar studies conducted on pollock indicated that the most appropriate method varies with stocks. The maximum age for pollock was extended to 28 years.

Results of a preliminary structure study on coho smolts from the Lachmach River showed that both otoliths and pectoral and dorsal fins have good potential as accurate alternate ageing structures for this species. (Contact: S. E. MacLellan)

Herring Research

Herring research provides the scientific basis for the conservation and rational management of this resource in British Columbia. To provide biological advice on stock status and catch recommendations for herring fisheries the major focus of research in recent years has been related to population dynamics. This includes the development and evaluation of analytical assessment methodology; development of hydroacoustic assessment methods; studies on recruitment processes and development of recruitment forecasting models; stock identification studies; development of methods for forecasting spawn timing; and studies on the effects of salmon netpens on herring. Research results and advice are communicated to fishery managers, clients and the scientific community.

Nearshore Habitat

In conjunction with an independent consultant and the B.C. Ministry of Agriculture and Fisheries, studies were conducted to examine the effects of salmon netpen wastes and predation on juvenile herring and salmon. In a field assessment of the effect of netpen wastes on herring eggs carried out at three farms in southern Johnstone Strait, survival and hatching of artificially fertilized herring eggs suspended in the vicinity of netpens were monitored over a two-week period. Relatively good egg survival was observed in each location although there were statistically significant differences in egg survival between farms. These were related more to ambient oxygen levels than to netpen wastes. Results of a concurrent laboratory study on the effects of salmon wastes on incubating herring eggs confirmed the requirement of herring eggs for high oxygen levels. The results indicated that the oxygen demand of netpen wastes could be deleterious to herring eggs if the eggs incubated on benthic macrophytes immediately below the netpens.

To investigate salmon predation in netpens, the stomachs of 1,705 salmon from nine fish farms were examined over a four month period between May and July. This period coincides with the exodus of juvenile salmon from Georgia Strait north through Johnstone Strait. Collections of fish and plankton were made in the vicinity of netpens to determine the abundance of wild fish potentially available to netpen fish. Only 0.6% of the stomachs examined contained remains of fish, all of which were juvenile herring. About 40% of the stomachs contained other types of feed - primarily planktonic invertebrates, the majority of which were derived from the unique "fouling" communities that develop on the netpen webbing. Young of the year herring and juvenile salmon were found at all sites during most of the sampling period, confirming that wild juvenile salmon and herring were generally abundant in waters surrounding the netpens. (Contact: D.E. Hay)

Recruitment Processes - Egg Survival

Science Review
1989/90

Egg mortality is one factor which may affect herring recruitment. In the final season of a two year field study in Lambert Channel, herring spawn and herring egg predators were sampled and enumerated. Preliminary results indicate that egg loss from spawn on *Sargassum muticum* was as high as 85% in shallow water and as low as 25% from spawn on red algae in deep water.

45

Both in 1989 and 1990, gulls increased in number from 20,000 at the beginning of herring spawning in early March to 40,000 birds in mid-March, declining rapidly to 1,000 birds in late March. Scoters increased from about 1,000 in early March to 15,000 (1989) and 30,000 (1990) by mid-March. In 1989, scoters had moved out of the study area by the end of March, but in 1990 they remained in the area. Other diving ducks increased from 2,000 birds in early March to 8,000 (1989) and 11,000 (1990) birds by mid-March and had not decreased significantly in number by the end of March. The maximum number of birds observed was 57,000 on March 15, 1989 and 61,000 on March 19, 1990. It is estimated that birds consumed over 200 tons of herring spawn in a three to four week period in both 1989 and in 1990.

Bottom feeding predators appear to consume at least as many herring eggs as birds, with four species of small crabs, three species of small snails, and four species of starfish accounting for about 80% of the eggs consumed by bottom predators. Egg loss to predators was about 8% of total spawn. A similar percentage of egg loss was probably due to physical displacement by wave action. (Contact: C.W. Haegele)

Recruitment Processes - Larval Surveys

In 1989, the entire area of Georgia Strait and many of the surrounding inside waters were surveyed and over 400 samples collected. Analyses indicate that herring larval distribution was continuous throughout the Strait of Georgia. However, larval abundances were greatest in the waters within 1-2 km of the shore. Highest concentrations were found on the east coast of Vancouver Island, between Ladysmith and Lambert Channel, and in the waters from Powell River to Cortes Island. (Contacts: D.E. Hay, B. McCarter)

Stock Assessment - Winter survey

Coastal waters within the 50-200 m bottom contour of Hecate Strait were surveyed in December using the CSS J. P. TULLY to determine Pacific herring abundance estimates and distribution patterns. Echo integration biomass estimates of midwater herring were 6,230 t at Browning Entrance, 17,500 t SW of Bonilla Island, 8,270 t in Juan Perez Sound, 7,910 t in Sedgwick Bay and 2,160 t in mid-Hecate Strait. Herring schools were difficult to integrate acoustically because of bottom echo interference during the day and a limited echo integration window near the surface at night. Best estimates, however, were ob-

tained just before dawn when herring were descending in the water column. The sum of hydroacoustic estimates in the Prince Rupert and Queen Charlotte Islands districts were intermediate between those derived from age-structure and escapement models.
(Contact: B. McCarter and D.E. Hay).

Stock Identification

The study of genetic differentiation of Pacific herring stocks using nuclear DNA analysis continued. Unfortunately, significant difficulties in obtaining high molecular weight DNA extractions were encountered. This may have been the result of excessive temperatures between capture of the specimens and their preservation. Nevertheless, it was possible to develop restriction maps for both Atlantic and Pacific herring.



Restriction map of ribosomal DNA extracted from Pacific herring. The restriction enzymes used are as follows: B= BamHI, H= HindIII, K= Kpn I, Ps= Pst I, Dra= Dra I, Xb= Xba I, E= Eco RI, Bgl= Bgl II.

asterisks () represent polymorphic sites*

The maps were very similar, especially in the coding region. The coding region sites found in herring were similar to those previously found in other teleosts although there were also several exceptions. Most of the sites in the non-coding region were unique to herring. Intraspecific variation in the non-coding region was found with several enzymes.
(Contact: J.F. Schweigert)

Catch Sampling and Data Base Management

Catch sampling and data base management provide the basic biological data for herring stock assessments and ensures the continuity and integrity of the herring data base. This in turn permits evaluation of various effects, such as climate change and the impacts of oil spills on the population dynamics of herring. The primary data sources are spawn survey data, commercial catch landing data, and biological sampling data from the commercial fishery, pre-fishery charter and research catches. This information, required for stock assessment, is available on a computer database for the period 1950 to the present.

The annual stock assessment process begins in the spring with the collection of biological data during the roe herring fisheries and surveys of the subsequent spawning escapement. During the 1989/90 season, 123 samples from 15 roe fisheries, 300 pre-fishery charter samples, nine food fishery, and 11 research samples were collected and processed for biological data. Herring spawns were surveyed by SCUBA divers. Spawn samples were also collected for escapement model evaluation. (*Contacts: J.F. Schweigert, L. Hamer*)

Stock Assessment

Stock assessment research develops and evaluates assessment methods and provides annual assessments and quota recommendations for PSARC. Using two assessment methods, an escapement model and an age-structured model, stock assessments are conducted annually for seven major migratory herring stocks. Results are presented in September at the annual PSARC Herring Subcommittee meeting to determine fishing quotas based on the best available biological data.

To provide overall stock forecasts for the seven stock assessment regions on the British Columbia coast, assigned probabilities were used to weight the forecasts of each of the two assessment models. While the forecast weighted run size for the seven regions for 1990 decreased slightly from the the corresponding forecast for the previous year, both approximated 200,000 t. (*Contacts: V. Haist, M. Stocker, J.F. Schweigert*)

Shellfish Research

The Shellfish Section provides biological and scientific advice for conserving, managing, and enhancing invertebrate and marine plant resources by conducting research on the distribution, life history, ecology, physiology and behaviour of commercial and potentially commercial invertebrate and marine plant species; conducting resource surveys and sampling of commercial catches for stock assessments; participating in research into the impact of natural and human-induced factors on the habitat of invertebrate and marine plant stocks; maintaining fishery databases; using and developing analytical methods to advise on appropriate exploitation; providing biological advice to fishery managers, and communicating research results to clients and the scientific community.

Scallop Culture

Scallop culture research continued as a joint project with the B.C. Ministry of Agriculture and Fisheries. Studies concentrated on the exotic Japanese scallop, *Patinopecten yessoensis* and the native rock scallop, *Crassadoma gigantea*.

All Japanese scallop broodstock used was produced in the experimental hatchery at PBS. Work continued to focus on the nursery stage of culture and included studies to improve the success rate at metamorphosis, improve the nutrition of juveniles in nursery systems, and reduce mortalities of juveniles by improved handling techniques. Studies to improve success at metamorphosis included treating mature larvae with different stimuli: neurotransmitters, norepinephrine, epinephrine, L-DOPA, serotonin; ammonia; and cold temperature shock. Significant increases in percent metamorphosis were observed when larvae were treated with norepinephrine, epinephrine and L-DOPA. Results with ammonia were variable and significant increases in percent metamorphosis depended on concentration and exposure time. No consistent significant increase in percent metamorphosis was observed when larvae were treated with serotonin or subjected to cold temperature shock.

Growth and mortality rates of newly metamorphosed Japanese scallops were analyzed. Higher numbers of juveniles attached to lightly fouled cultch and the presence of an epifloral film significantly enhanced early post-metamorphic growth. The nutritional importance of epifloral films for juvenile growth was, however, much less than that of suspended algae. Heavy losses occurred in most nursery sets before the juveniles attained 400 microns of juvenile shell growth, especially in sets that experienced the greatest metamorphic success. A second critical period, characterized by reduced growth rates and heavy mortality rates, was observed when juveniles were about 600 microns dissoconch height.

In studies on the nutritional requirements of juvenile scallops, initial observations indicated that diet supplementation with wild microalgae enhanced juvenile performance at 0.5-1.0 mm shell height, indicating

that cultured microalgal diets used may have been qualitatively inadequate. Investigations to determine if these mortalities were due to the poor nutritional quality of the cultured algae or whether larger-sized algal cells are required when juveniles attain a shell height of 0.5 mm indicate that larger-sized algal species improve growth and mortality rates. These studies are continuing.

About 20,000 juvenile Japanese scallops were produced for use as broodstock at PBS and a commercial scallop hatchery, and in growout trials undertaken by the B.C. Ministry of Agriculture and Fisheries. An improved method for reducing mortalities of juvenile scallops when being transferred from spat bags to pearl nets was developed.

A commercial scallop hatchery and nursery built in Qualicum Bay will use hatchery-nursery technology based on work conducted at PBS. Program staff assisted in transfer of this technology. Publication of *A Manual For Scallop Culture In British Columbia* in 1989 should facilitate transfer of information from the scallop culture program to industry. (Contact N.F. Bourne).

Invertebrate Nutrition

The major anatomical changes in bivalve development occur at embryogenesis and metamorphosis. These changes are fuelled by stored energy reserves which are crucial to the successful transitions of the egg to pelagic larva and the premetamorphic larva to spat. Endogenous reserves in the egg derived from the parent are catabolized initially during embryonic development, from fertilized egg to straight hinge veliger or D-larva. A continued reliance on these reserves was evident from the decline in total energy in the Japanese scallop, *Patinopecten yessoensis*, larvae during the transitional stage to exogenous feeding. Previous studies on embryogenesis of the rock scallop, *Crassadoma gigantea*, demonstrated the substantial depletion of stored reserves in eggs and the significance of egg reserves to successful bivalve rearing. In both species of scallop protein and lipid were equally important as sources of energy during their embryonic development.

The second stage of bivalve larval development where stored reserves are crucial is prior to metamorphosis and depends on the food value of algal diets supplied to the growing larvae. Nutritionally superior diets provide premetamorphic larvae with sufficient stored energy to survive the second intense anatomical change at metamorphosis. Essential fatty acids (EFA) in marine aquaculture, eicosapentaenoic acid and docosahexaenoic acid are derived in the food chain mainly from phytoplankton. The effects of light intensity on the production of fatty acids in phytoplankton were determined using eight species grown under a range of photon flux densities (PFDs). Fatty acid composition changed considerably at different PFDs as the percentage of specific fatty acids covaried with PFDs, growth rate or chlorophyll α content per cell. Results suggested that fatty acid composition was a highly dynamic component of cellular physiology, which responded significantly to variations in PFDs.

The nutritional changes in adult oysters, *Crassostrea gigas*, subjected to complete starvation, partial feeding and oceanic feeding for 405 days were assessed. Whole wet weight and dry meat condition index increased in the fed oysters and decreased in both the partially fed and starved oysters over the holding period. Total starvation resulted in significant linear losses of wet weight, insoluble ash, lipid, glycogen, sugars, protein and non-protein nitrogenous compounds from body tissue; conversely, moisture, soluble ash, chloride and iodide increased with total starvation. The decline in constituents of partially fed oysters was similar, but not as extreme as in totally starved oysters, and differed from increases in fed oysters. Irrespective of nutrient conditions, changes in adductor muscle were minor relative to those in the body tissue. *C. gigas* maintained an acceptable nutritional condition for 100 days and survived over 400 days of complete starvation, which indicated that deep-water holding of well-nourished oysters without quality loss was feasible. (Contact: J.N.C. Whyte)

Blue Mussel Culture

Research focused on completion of studies on site-specific variation in survival initiated in 1988 and acquisition and spawning of Atlantic mussels to assess their performance in Pacific waters. Investigation of the genetic versus environmental (site) components of mortality involved the growout of mussels collected at four sites (Barkley Sound, Okeover Arm, Jervis Inlet and Indian Arm). A multiple transplant experiment was established at each seed source site to determine whether certain mussel strains survived better under different environmental conditions. Preliminary results suggest that while some strain and site variation in mortality occurred, mortality at all sites was high and was not overcome by seed source. (Contact: G.S. Jamieson)

Mussels were acquired from Nova Scotia in the spring of 1989, and held in quarantine. Some were spawned and, after ensuring that the progeny were disease-free, were reared in a flow-through system to allow comparison of their growth and survival with local mussels. Survival rates were more or less equal, but the N.S. juveniles grew at about twice the rate of the B.C. juveniles. Growth of both strains slowed noticeably in November, at which time the N.S. and B.C. juveniles averaged about 13 and 7 mm long, respectively. In trial studies of adult survival, mussels were held in quarantine in a flow-through system, where they were fed with pumped, unfiltered sea water. All B.C. mussels died by mid-August, while the mortality of N.S. mussels was about 5-10%. There definitely appears to be a genetic difference in longevity between the two strains, with the B.C. mussels dying after spawning only once and the N.S. mussels living a number of years. (Contact: G.S. Jamieson)

Fishery Studies

Science Review
1989/90

Stock assessment studies provide both short and long term evaluations of commercially-harvested invertebrate species. Assessments are based on population surveys conducted from research and commercial fishing vessels as well as catch and effort data supplied by industry through mandatory logbook programs.

51

Analysis of logbook data and Fishery Officer activity logs for prawn and shrimp fisheries provides short and long-term catch and effort trends and facilitates evaluation of stock status in small geographic areas. This ability is crucial in the assessment of local fishing pressures or environmental issues. Annual summaries of catch and effort for the shrimp and prawn fisheries are sent to individual fishers.
(Contact: J.D. Fulton)

Annual stock surveys are conducted to provide estimates of biomass and year class strength for shrimp, prawns and Dungeness crab. Biological samples were collected from off-shore shrimp stocks, prawn populations in the experimental management areas and the Tofino crab fishery. These data are used to determine the relative size of the population, expected yields for the current fishing season, and prospects for future fisheries. (Contacts: J.A. Boutillier, G.S. Jamieson)

Studies were conducted on destructive release mechanisms to ensure that lost crab traps cease fishing and to determine optimal escape ring diameter for Dungeness crab traps. Untreated cotton twine, #36 thread in size, was recommended as best for a release mechanism and was introduced as a requirement for the 1990 season.

Escape ring studies compared the performance of the currently required diameter of 100 mm with 106, 108, 110 and 112 mm diameter rings. For the currently regulated minimum legal size of 165 mm spine-to-spine carapace width, the optimal diameter was 110 mm. This did not significantly reduce the catch of legal-size crabs but did reduce significantly the catch of prerecruit crabs. (Contact: G.S. Jamieson)

Prawn Studies

Studies continued on the assessment of the biological impacts of a commercial fishery on prawn stocks by experimentally manipulating the commercial fishery with respect to exploitation rates, seasonal timing and duration of the fishery. Data from this study have allowed for definition of fishing periods which will maximize catch in areas of high exploitation. Tagged prawns were successfully released and recaptured in the commercial fishery for the first time in B.C. The results of the tagging data indicated that prawns have very limited movement over the grounds, an extremely important factor in establishing boundaries for such things as dioxin closures. (Contact: J.A. Boutillier)

Invertebrate Stock Identification

Effective fisheries management is dependent upon the ability to identify distinct stocks which constitute a population of a single species. Inorganic elements and fatty acids were identified as possible markers for stock identification in the spot prawn, *Pandalus platyceros*. Although the results of this research indicated that neither of these characteristics could in fact be used for stock identification purposes, the levels obtained for metallic elements in the prawn provided a measure against which future environmental impact could be assessed.

(Contact: J.N.C. Whyte)

Recruitment Studies

Investigations of the biology and early life history of Dungeness crab (*Cancer magister*) continued in studies to understand the primary factors affecting magnitude of recruitment. Studies again focused on both the west coast of Vancouver Island off Tofino and in the Strait of Georgia. One cruise was conducted in each area. Off Tofino, it was noted that the Vancouver Island Coastal current was temporarily reduced in intensity in May and June and that a substantial crab settlement occurred throughout the area. In the previous four years, the current was relatively strong during this time period. Most megalopae were prevented from coming onshore before they settled, resulting in poor larval settlement in nearshore areas and a prediction that landings from the Tofino area would be reduced. In the Strait, larval abundance was high in most of the areas surveyed. Larvae here are apparently retained in inshore waters and do not disperse in the manner outer coast larvae do. Rather than move offshore, Strait megalopae appear to move to about 150 m depth during the day, suggesting that both groups of larvae may be avoiding some factor present in nearshore surface waters during daylight. (Contact: G.S. Jamieson)

Invertebrate Dive Fisheries

Experimental research on invertebrate dive fishery species was initiated with studies of growth and recruitment of sea cucumbers (*Parastichopus californicus*) and gonad quality of red sea urchins (*Strongylocentrotus franciscanus*). A double anchor tag was developed for sea cucumbers and is currently being tested for long term retention. The tag will assist in determining growth rates and movements of the sea cucumbers. A settlement collector was developed to determine the seasonality and quantity of sea cucumber recruitment and is being tested. An additional feature of this collector is that the growth rate of post-settled juvenile sea cucumbers can be monitored. On-going collections of red sea urchins are being made to determine seasonal changes in gonad quality in terms of relative gonad weight, colour and chemical composition. (Contact: A. Campbell)

Ocean Ecology Research

Science Review
1989/90

53

The Ocean Ecology group at IOS investigates natural variations and the consequences of human-induced stress in marine planktonic and benthic ecosystems. The objective of this research is to provide advice and predict real or anticipated impacts of natural variability and human activity. The plankton program's focus is on understanding the linkages between ocean variability and responses of lower components of the marine food web on a wide spectrum of time and space scales. The focus in the benthos program is on the description of the benthic community in a natural state, its response to stress, and the use of that response as an indicator of broader ecosystem change.

Plankton

The plankton group was extensively involved in the La Perouse and Marine Survival of Salmon (M.A.S.S.) Projects.

The goals of research conducted for the La Perouse Project are to describe and quantify seasonal and interannual variability in plankton biomass and community composition for the southern Vancouver Island outer coast, and to learn whether lower trophic level variability is transmitted up the food chain to commercially exploited stocks. Although the continental shelf and slope zone off Vancouver Island is relatively narrow, distinct oceanographic regions (based on water properties, plankton biomass and composition, bathymetry, and current pattern) have been identified in previous studies.

The present sampling scheme is based on multiple sampling within three regions: region A - outer bank edge, shelf break and slope; regions B and D - inner banks and basin off Barkley Sound; and region C - shelf region south of the major banks; Juan de Fuca canyon and gyre system. The use of several stations within each region allows an estimate (and averaging out) of local patchiness. To determine the extent to which within-time-period sample groupings based on species composition match these hydrographic regions, a multivariate cluster analysis was used to identify samples with similar species dominance hierarchy for each of the twenty-six time periods (cruises) sampled to date. Within each time period there were usually three compositionally distinct subgroups. Overall cluster membership corresponded well with region membership, although a few sites showed frequent crossovers to adjoining regions.

After five years of sampling, an "average" seasonal cycle of species composition in each of the regions is slowly emerging. Region A is dominated in spring and early summer by chaetognaths and by large Subarctic Pacific copepods, mostly of the genus *Neocalanus*. In two out of the five years sampled, this region had high biomass of offshore gelatinous zooplankton species (salps, siphonophores and doliolids) in late summer and autumn. Region B is dominated in spring and early summer by the smaller copepods *Calanus* and *Pseudocalanus* and by

hydromedusae. Total zooplankton biomass is on average lowest in this region. It peaks late spring to early summer, then declines later in the year. The euphausiids *Euphausia pacifica* and *Thysanoessa spinifera* make up much of the relatively low late summer zooplankton standing stock. Region C has the highest average zooplankton biomass and is intermediate in species composition between Regions A and B. The most striking feature of the multi-year average seasonal cycle is a late summer/early autumn maximum in euphausiid biomass; much of this peak is due to relatively high euphausiid abundances observed in 1988 and 1989. The seasonal cycle for the copepod species was more consistent between years. *Calanus* biomass peaked in June-July in Region C (vs. April-May in Region B and July-August in Region A). (Contacts: D.L. Mackas, R.M. Brown).

M.A.S.S. related research was conducted in two geographic areas on the west side of Vancouver Island: Barkley Sound and areas adjacent to Brooks Peninsula.

The objective of the Barkley Sound work is to examine spatial gradients of plankton standing stock, community and size composition within Barkley Sound as possible predictors of smolt migratory corridors and residence time. This includes investigation of temporal change and underlying biological and oceanographic processes controlling the zooplankton community. The first study conducted in late April 1987 focused on description of inlet-scale spatial variability of size-fractionated primary productivity and phytoplankton. Vertical net hauls at nine locations throughout Barkley Sound showed high biomass of larger-bodied zooplankton in the areas that sockeye smolts were then most abundant. More detailed studies of the size distribution of zooplankton throughout the water column and in the surface layer conducted in May 1988, showed a substantially different pattern. Small copepods (less than 1 mm in length) were dominant everywhere in the surface layer, while larger crustaceans (euphausiids, amphipods) were restricted to deep locations in Alberni Inlet, Trevor Channel and seaward of Ucluelet. Highest zooplankton densities occurred in more saline water in the outer area of Barkley Sound.

The objective of the 1989 field program was to amplify the information on zooplankton distribution, abundance and size structure. Two surveys were conducted in May and June, each consisting of continuous underway mapping of the surface distribution of zooplankton biomass by size category, salinity, temperature and chlorophyll fluorescence throughout Barkley Sound. The mapping was supplemented by sampling at nine stations. At each station zooplankton were collected by vertical net haul for size-frequency distribution, identity and abundance. CTD profiles were obtained and discrete water samples were collected at three depths for analysis of bacteria abundance, phytoplankton identity and abundance, and chlorophyll, particulate carbon, and nitrogen, and dissolved inorganic nutrient concentrations.

The physical structure observed in 1989 resembled that observed in 1987 and 1988. Alberni Inlet and Barkley Sound are strongly stratified with a surface layer of brackish water, generally less than 5 m thick. This layer increases gradually in salinity seaward, but is largely discon-

nected from the layer of underlying water. In May 1989, as in 1988, surface zooplankton were largely absent in the surface layer. The largest aggregations were found in a band across central Imperial Eagle Channel and, to a lesser extent, in Trevor Channel. Practically none were found in Alberni Inlet. Unlike 1988, concentrations were low in outer Barkley Sound. The size structure of these populations differed substantially from 1988. In 1988, surface zooplankton were dominated by small copepods, with some ctenophores. In 1989, areas with high biomass were dominated by larger organisms, in particular brachyuran crab zoeae and large copepods with effective body volumes of 1 - 2 mm³. (Contact: J.R. Forbes)

In the Brooks Peninsula area, cold water "filaments" are common features of summer satellite images. In 1986 and 1987, filaments were located and followed at their offshore extensions to establish their trajectories and monitor the development of plankton populations contained within the filaments. Oceanographic observations were carried out in the immediate vicinity of Brooks Peninsula in August, 1988 to assess whether this cold water could form a barrier to the migration of juvenile salmon. The results indicated that there was little or no northward flow past Brooks Peninsula and that the shelf-break current penetrated to within a few kilometres of the shore.

The August, 1989 results were much different. The pattern of cold, recently-upwelled water off Brooks Peninsula was evident, but a well-developed northward-flowing Vancouver Island Coastal Current (VICC) was observed within 20 km of the shore and the southward flowing shelf break current further offshore. There was indication of a back-eddy to the north of the Brooks Peninsula and a gyre (counter-clockwise) centred approximately 35 km to the west of Brooks Peninsula. The current patterns from the vessel-mounted acoustic Doppler current profiler (ADCP) were confirmed by tracks of surface drifter buoys. As in 1988, there was very little tidal signal in the surface water movements, making the ADCP a particularly useful tool in this area. Although the significance of the 1989 oceanographic regime around Brooks Peninsula with respect to the migration of juvenile salmon remains untested, the strong residual currents in this area, (often greater than 30 cm/sec), and evidence of substantial cross-shelf advection represent possible obstacles to the migration of juvenile salmon. (Contacts: K.L. Denman, R.M. Brown).

Benthos

A study of the benthos of Vancouver Harbour (Burrard Inlet) was carried out in cooperation with the Environmental Protection Service (EPS) of Environment Canada. Recently developed statistical analyses were used to detect clusters of sites with similar benthic communities, clusters of sites with similar chemical conditions, and a comparison of these two patterns. Considerable agreement between the chemical and benthic data was demonstrated statistically.

One group of sites along the industrial north shore of the harbour (to the east of Lions Gate Bridge), together with a single site on the south shore, differs from a larger group of sites covering most of the Inner Harbour. These two groups of sites cannot be recognized on the basis of total numbers of benthic species or total numbers of organisms. They are separable only on the basis of the identity of the species and differences in their relative abundances, which cannot be recognized by inspection of the tabulated information because the differences are subtle. Despite the very high levels of human activity in these areas, biological data suggests that ecological conditions are good, probably as a result of the very high rate of water exchange through the First Narrows. In the Eastern Harbour (including Port Moody Arm), the number of species and of individuals is clearly much lower.

The study was extended this year to include simultaneous measurement of sediment toxicology as well as sediment chemistry and benthic ecology at 20 of the stations visited initially to determine human affects on the environment.

In a joint cruise with EPS, a fourth visit was made to Alice Arm to check on the recovery of the benthos following cessation of the disposal of mine tailings into deep water. Additional fjord sampling was carried out in Work Channel, Douglas Channel and Seymour and Belize Inlets.

A major review of marine benthic community analysis was completed. The review includes studies on the continental shelf, Hecate Strait, Alice Arm and the mainland fjords and shallow water sites such as Burrard Inlet and Boundary Bay. This will provide a basis for future environmental assessment of human impact on marine ecosystems. The studies include uncontaminated areas, sites of known contamination and areas that suffer from environmental stress from natural causes, such as restricted water circulation.

Work on aquatic oligochaetes continued. Two international cooperative efforts resulted in the production of illustrated reviews and guides to these pollution indicator organisms from South and Central America and the People's Republic of China. Evolutionary studies proceeded with a publication on the subfamily Tubificinae and manuscript preparation on the family Phreodrilidae. Collections submitted for identification by applied biologists were processed, and a few small studies of individual species were published as a result. One interesting discovery was the arrival of a pollution-tolerant Atlantic Ocean marine sludge worm in Vancouver Harbour, the first Pacific Ocean record. This appearance is a sign of the frequency with which animal species are transported around the globe by human agencies. Some of these introductions, such as that of the Zebra Mussel into the Laurentian Great Lakes, create considerable economic problems.
(Contact: R.O. Brinkhurst)

Aquaculture Division

Science Review
1989/90

The Aquaculture Division was created one year ago to provide a focus for aquaculture and enhancement research. The Division consists of the Fish Health and Parasitology, Fish Culture and Biotechnology, Genetics and Nutrition sections, and has functional responsibility for shellfish and marine species aquaculture. The Aquaculture Division Head acts as a contact point for liaison with the aquaculture industry and for federal/provincial relations related to aquaculture research matters. (*Contact: T.A. Tebb*)

57

Biotechnology, Genetics and Nutrition Research

Activities in the Biotechnology, Genetics and Nutrition Section are directed towards the development of technologies for improving the feasibility and economic viability of commercial finfish aquaculture. Research also contributes to the enhancement and management of wild stocks. The Biotechnology and Genetics components of the section comprise the DFO Centre of Disciplinary Expertise (CODE) for Biotechnology and Genetics in Aquaculture. (*Contact: E.M. Donaldson*)

Reproduction Biotechnology

Transfer of technology for production of monosex chinook salmon sperm for the production of all-female chinook stocks for the B.C. salmon mariculture industry was completed successfully in 1989. (*Contact: E.M. Donaldson*)

Research continued on the development of monosex sperm from coho and Atlantic salmon and on techniques for the production of chinook monosex sperm from different genetic backgrounds. Combinations of hormonal and genetic techniques (chromosome set manipulation/gynogenesis) were tested for production of phenotypic males of female genotype. Treatment parameters for sperm irradiation, heat or pressure shock intensities and duration for the induction of coho and Atlantic salmon gynogenes and triploids were investigated. (*Contact: I.I. Solar*)

Research on the use of brain peptide analogues for the induction of ovulation of salmonids, sablefish and Pacific halibut continued. Several gonadotropin-releasing compounds (D-Ala⁶, D-Trp⁶ and five lamprey GnRH analogues) were tested in coho salmon. The most potent, D-Ala⁶desGly¹⁰ethylamide LHRH analogue was also used to induce ovulation in sablefish in continuation of the marine fish mariculture program. (*Contact: I.I. Solar*)

Aquaculture Biotechnology

The growth promoting efficacy of various recombinant somatotropins (rsts) for Pacific salmon was examined. An integral component of such evaluations is the screening of oral and sustained delivery techniques for delivering rsts. Recently completed studies demonstrated that one-time implantation of sustained release pellets containing recombinant porcine somatotropin provided a highly effective method of accelerating growth in coho, over extended periods of time (> 6 months). Oral administration of recombinant bovine somatotropin to coho salmon resulted in growth acceleration. Techniques which may assist in the protection of orally-delivered rsts from degradation during transport along the gut are currently being surveyed. (Contact: E. McLean)

Molecular Biology

A molecular biology facility was established at the West Vancouver Laboratory (WVL) to examine aspects of fish biology and genetics related to aquaculture and wild-stock evaluation. The current focus of the research is the implementation of recombinant-DNA methods to isolate and characterize salmonid genes that influence commercially important characteristics such as growth rate and reproduction. Two distinct types of genes for somatotropin (growth hormone) have been successfully isolated from sockeye salmon, and characterization of their sequence structure has been initiated in preparation for further studies on their expression, and for manipulation of their regulatory properties to allow expression in bacteria (for the production of active protein) and in transgenic fish (to improve production characteristics). In view of the potential of these genes and their products to reduce feed costs by improving growth rates and overall feed conversion efficiencies, there is considerable interest in the commercial application of this research. (Contact: R.H. Devlin)

In a project designed to reduce the time required to produce all-female strains of chinook salmon for the aquaculture industry, a program has been initiated to identify and isolate male-specific DNA sequences by recombinant-DNA methodologies that would allow identification of individuals containing a Y chromosome. This work is being carried out in cooperation with a commercial salmon farm and is funded by the Science Council of B.C. (Contact: R.H. Devlin)

Studies of several other genes have been initiated to manipulate the processes influenced by these genes and to develop molecular assays to evaluate particular physiological conditions (e.g. exposure to stress). These include the genes for heat-shock proteins (involved in stress tolerance), P450 mono-oxygenase enzymes (involved in detoxification of toxic compounds, or in the synthesis of sex steroids), other growth factors such as somatostatin and insulin-like growth factors, and additional promoters for use in transgenic experiments (metallothionein, histone H3, and the male-germ-line-specific promoter, protamine). (Contact: R.H. Devlin)

Salmon Genetics

Science Review
1989/90

59

A molecular genetics laboratory was established to develop and implement stock-specific DNA probes for use in mixed-fishery analysis. DNA probes isolated from chinook salmon are now being tested in the lab for their stock specificity and fingerprinting capability. Fingerprinting probes allow the identification of individuals to the family level, and have potential application in salmon enhancement and aquaculture operations. (Contact: T.A. Stevens)

The first generation (F_1) of selected coho in the odd-year broodline was established from a baseline population consisting of purebred and hybrid Robertson Creek, Quinsam River, and Kitimat River coho. Broodstock was chosen on the basis of superior BKD resistance, superior smoltification as age 0+ fish, and body weight after nine months in salt water. All three traits were demonstrated to be heritable, and the genetic correlations among them are 0 or positive, indicating that selection to improve all three traits simultaneously in the odd-year coho broodline should be successful. Performance in the selected coho line will be compared with that of wild Kitimat river families established in November 1989 as a control line. (Contact: R. Withler)

Smoltification success and nine-month saltwater size have been recorded for over 2,000 PIT-tagged individuals from 100 families of coho salmon in the even-year baseline population for selective breeding. Individuals will be chosen from the top two performing stocks (Kitimat River, Quinsam River) for spawning in the fall of 1990 to establish the first selected generation (F_1) in the even-year line. (Contact: R. Withler)

Studies on chinook salmon have shown that differences between ocean-type and stream-type populations in juvenile life history patterns and tolerance of high water temperatures are under genetic control. Some stocks are therefore likely better suited for enhancement operations and aquaculture than others. A study to determine the number of genes and their modes of action in controlling juvenile life history (age of smoltification) in chinook salmon is underway. (Contacts: C.W. Clarke, R. Withler)

Fish Nutrition

Comparisons of the proximate and fatty acid compositions of the edible portions of farmed and wild coho and chinook salmon have been conducted to develop a baseline for optimization of the composition of market-size farmed salmon.

An experiment aimed at assessing the nutritive value of poultry-by-product meals for chinook salmon in seawater indicated that there is good potential to replace up to 75% of the herring meal with poultry-by-product meal in formulated diets for this species. Research is underway to confirm the preliminary findings. (Contact: D.A. Higgs)

Several studies on the digestibility of various fishmeals, poultry-by-product meals, feather meal, blood meal and several sources of plant proteins by chinook salmon in seawater were completed and a table of feedstuff digestibility coefficients for chinook salmon in seawater compiled. This information is essential to formulate diets on a least cost basis and for obtaining feedstuffs of the highest potential nutritive value for inclusion in formulated diets for Pacific salmon. (Contact: D.A. Higgs)

Stress and Histopathology

In continuing studies to assess protein sources for salmonids, un-dephytinized and dephytinized rapeseed protein concentrates were evaluated as dietary components for juvenile rainbow trout. A marked thyroid hypertrophy/hyperplasia was noted in many, but not all fish fed the diets containing the higher portions of rapeseed concentrate. Further studies will be required to elucidate the factor(s) responsible for the heightened thyroid activity. (Contact: D.A. Higgs)

In studies to examine the secondary responses of juvenile coho to hormonal sterilization, it has been noted that such responses (thickening of skin epidermis, minor structural alterations in kidney and liver, as well as changes in the flesh proximate analysis), are reversible six-nine weeks after withdrawal of the androgen. (Contact: D.A. Higgs)

Fish Culture Research

Research is conducted in three program areas: Incubation and Water Quality, Aquaculture Environmental Factors, and Aquaculture Seawater Husbandry. Staff also operate and maintain the Experimental Mariculture Facility in Departure Bay. Studies are aimed at improvement of existing culture methods and the development of innovative new technologies for transfer to fish culturists in the public and private sectors. (Contact: W.C. Clarke)

Incubation and Water Quality

Work continued on the development of incubation methods for sablefish and Pacific halibut. The pelagic marine eggs and larvae of these species are spawned at great depths where temperature and salinity vary little. These conditions were simulated in upwelling incubators using a computerized system to maintain constant temperature and salinity in the incubators. The computer-controlled valves regulated the flow of ambient and chilled sea water to deliver a constant temperature of 6 °C at a set flow rate. Eggs collected from captive sablefish and Pacific halibut which were induced to spawn by hormonal injections were not viable and none survived to hatch. Eggs collected from wild sablefish were incubated successfully and more than 50,000 hatched

larvae were produced. Another experiment demonstrated that fertilization success was high over a range of salinities from 25 to 40.

(Contact: J.O. Jensen)

Science Review
1989/90

Aquaculture Environmental Factors

61

An experiment conducted at the Experimental Mariculture Facility demonstrated that artificial light could be used to delay the onset of sexual maturation in pen-reared coho and chinook salmon by two to three months. This provides a simple procedure by which salmon farms can postpone the harvest of maturing salmon until after the commercial fishery is completed and the selling price is higher.

Progeny of crosses between domesticated rainbow trout and steelhead trout were reared in a laboratory study of the genetic control of growth and seawater adaptation. The results demonstrated a quantitative difference between the hybrids and steelhead trout with respect to their seasonal patterns of growth and seawater adaptability. This suggests that these traits are under the control of a number of loci.

(Contact: W.C. Clarke)

Aquaculture Seawater Husbandry

Results of an experiment initiated to determine the influence of temperature on the optimum ration for growth and feed conversion of chinook salmon in sea water, indicated that food conversion efficiency improves slightly with reduced ration and is decreased at temperatures below 9°C.

Analysis of results of a chinook broodstock strain comparison experiment involving six populations of salmon in commercial culture revealed that the rearing environment explains up to 80% of the variation of fish weight at harvest. (Contact: H. Kreiberg)

Fish Health and Parasitology Research

Research in this section concentrates on determining causes of diseases of fish (particularly salmonids) and shellfish and developing methods for their prevention and control in government enhancement facilities and commercial aquaculture. Staff participate in the development and implementation of policies to prevent the introduction and spread of diseases of aquatic resources in the Pacific Region and organize and participate in fish health workshops and courses. Research is also directed at assessment of the impact of diseases and parasites on the ocean survival of salmon and exploring the use of parasites as natural markers for stock identification in salmon for domestic and international fisheries management. (Contact: L. Margolis)

Bacterial Kidney Disease (BKD)

Two procedures were developed for obtaining consistent growth of the kidney disease bacterium on culture media, regardless of variances in peptone lots. The first involves the use of the nurse culture technique — a technique that also has the advantages of accelerating growth of the pathogen and of increasing the sensitivity with which it can be detected. In the second procedure the culture medium is supplemented with a small amount of broth previously used to grow the pathogen (spent broth). Spent broth contains autoclavable metabolites that reproduce the effect of the living nurse culture. These findings will facilitate studies on the epizootiology of BKD. (Contact: T.P.T. Evelyn)

The kidney disease bacterium may not survive as long in the environment as *in vitro* studies using sterile suspending media suggest. The blue mussel (in 50 g/L of sea water) clarified turbid suspensions of the pathogen within 24 hours at 10°C and accounted for a 50% loss in the number of viable cells of the pathogen in this period. The mussel appears to accomplish this by digesting the pathogen. Overall, mussels appear to remove the pathogen from the water column by sedimenting it in the faeces and by digesting some of the ingested pathogen. Mussels may, therefore, play an important role in reducing the numbers of BKD organisms around salmon farms. (Contact: T.P.T. Evelyn)

Vibriosis

The failure of vibrio vaccines to function effectively in farm-reared chinook salmon appears to be a species-associated phenomenon. In a recent field study, chinook salmon died at approximately the same rate due to vibriosis regardless of the method of vaccine administration and despite the fact that the vaccine contained more than adequate amounts of the immunizing substance (the vibrio lipopolysaccharides). The problem may therefore be related to an inferior ability of chinook salmon to react to the immunogen — an ability that may vary with the physiological state of the animal at the time of vaccination. (Contact: T.P.T. Evelyn)

Viral Diseases of Salmon

Infectious hematopoietic necrosis (IHN) virus causes severe losses of sockeye salmon fry in spawning channels in B.C. It was determined that the virus is not carried latently throughout the marine life of the salmon, but is most likely acquired and amplified by adult sockeye after reaching the spawning grounds. Adult or spawned-out sockeye then release virus back to the environment. (Contact: G.S. Traxler)

A strain of infectious pancreatic necrosis (IPN) virus was isolated from apparently healthy Atlantic salmon being raised in netpens. This is the first reported isolation of an aquatic birnavirus from B.C. This strain of the virus is closely related to a strain of IPN virus previously isolated

from brook trout at Jasper, Alberta. Its distribution appears to be limited as tests of other groups of fish at the same site and other rearing sites failed to detect the virus. The B.C. isolate was found to be non-pathogenic for rainbow trout and chinook and coho salmon. (Contact: G.S. Traxler)

Marine Anemia (Plasmacytoid Leukemia) in Chinook Salmon

Marine anemia, a serious infectious disease of pen-reared chinook salmon, has been detected in fish from 11 farm sites in the Sechelt area. Although the disease has been detected in the field only in chinook salmon, sockeye salmon and Atlantic salmon have been experimentally infected with the disease by injection of affected tissues. Laboratory cohabitation experiments suggested that the disease is not highly transmissible by water-borne exposure in sea water. Studies are underway to determine the etiology of marine anemia, and preliminary results indicate that an oncogenic retrovirus may be associated with the disease. (Contact: M.L. Kent)

Netpen Liver Disease of Atlantic Salmon

Netpen liver disease is apparently caused by an unidentified water-borne toxicant. The disease commonly occurs in Atlantic salmon during the summer months, and may be caused by an algal toxin. In collaboration with Drs. Raymond Andersen and Max Taylor of the University of British Columbia, studies are underway to identify the source and chemical structure of the toxin, and to determine the algal profile of affected sites. (Contact: M.L. Kent)

Myxosporean Diseases

Proliferative kidney disease (PKD) is a serious disease of cultured salmonids reared in fresh water above 15°C. The causative agent is a myxosporean, and salmonids are probably abnormal hosts for the parasite. Previous observations suggested that the parasite is an immature form of *Sphaerospora* sp. that undergoes complete sporulation in sticklebacks. However, transmission studies indicate that the stickleback parasite is a different species. (Contact: M.L. Kent)

Myxosporean protozoans are important parasites of salmonids and other fishes, causing disease, affecting the quality of fish products, and serving as biological tags for stock identification. Little is known about their life cycles and mode of transmission. Studies on these aspects of their biology, particularly to determine if aquatic oligochaetes or crustaceans may serve as intermediate hosts, are underway using *Myxobolus arcticus*, a parasite of the central nervous system of salmonids. (Contacts: M.L. Kent, L. Margolis)

Disease Control Activities

The Fish Disease Control Program is responsible for the health of the salmonid stocks cultured in federally operated facilities and for provision of a fish health diagnostic/advisory service to federal fish culturists, field biologists, fishery managers, and researchers. Assistance is also provided to B.C.'s aquaculture industry when farmers face new or unusual disease problems. Staff also administer the Canadian Fish Health Protection Regulations within the Pacific Region and provide assistance to the joint Federal/Provincial Transplant Committee which adjudicates transplant of fish and other aquatic animals in B.C. (*Contacts: G.E. Hoskins, D. Kleser*)

The occurrence of disease agents known to cause high mortalities among cultured or wild salmonids is documented in disease surveys. This information is used in planning salmonid enhancement strategies and by the Transplant Committee to determine which stocks of salmonids can be moved safely to new areas for management purposes.

Following discovery of the causative agent of viral hemorrhagic septicemia (VHS) (previously known only in Europe where it causes high mortalities in cultured rainbow trout) in Washington State in 1989, an extensive survey of wild and cultured salmonids in the lower Fraser drainage and on southern Vancouver Island was undertaken. Although recent findings in Washington State suggest that the virus is probably well-established on the Pacific coast, the virus was not detected in the B.C. survey. Current work in the U.S. indicates that the VHS virus strain isolated in Washington may have a marine origin; therefore further monitoring for the virus will concentrate on adult salmon returning to federal facilities in the southern half of B.C..

Some 256 investigations of fish health problems in federal salmonid enhancement facilities were undertaken. The infectious diseases mainly responsible for mortalities at these facilities are:

	<u>No. of Cases</u>
1. Bacterial kidney disease	41
3. Bacterial gill disease	18
4. Furunculosis	20
5. Fusiform disease	7
6. Vibriosis (seacages)	6
7. Sporocytophagosis (seacages)	6

The above are all bacterial diseases that can cause high losses if careful fish husbandry procedures are not followed and if corrective measures are not quickly taken following diagnosis.

Most of the assistance provided to the aquaculture industry was related to the requirement to meet U.S. Federal Title 50 Regulations, which prohibit the entry of cultured fish into the U.S. unless the source facility has been inspected and certified free of the causative agents of whirling disease and VHS. More than 145 Title 50 certificates were

issued to seafarm operators. Assistance and training were provided to private diagnostic laboratories to permit them to assume this certification responsibility. (Contact: G.E. Hoskins)

Nine private trout farms were certified in 1989 in compliance with the Canadian Fish Health Protection Regulations. The Transplant Committee adjudicated approximately 510 applications to transport fish within B.C. (Contact: J. Kieser)

Shellfish Diseases

In addition to routine surveys conducted on oysters from seven localities, 29 investigations into unusually high mortalities or disease conditions were conducted. Mortalities among Manila clams on many beaches along the east side of Vancouver Island during late March and early April, 1989 were attributed to freezing during low tides in January and February of that year. Oyster mortalities were attributed to either poor culture techniques or Denman Island Disease in the spring and to nocardiosis in the late summer. Disease certifications were carried out on one group of oysters, one group of mussels, and one group of Japanese scallops to permit export to foreign countries. (Contact: S.M. Bower)

An atlas of anatomy and histology of larval and early juvenile stages of Japanese scallops was published to provide baseline information against which the health status of cultured scallops can be assessed during early developmental stages. (Contact: S.M. Bower)

Investigations into high mortalities among cultured Japanese scallops at seven locations during the grow-out phase did not reveal the presence of an etiological agent. However, lesions of inflammation, frequently with associated encapsulation and necrosis, were observed in 50% to 100% of the Japanese scallops from all locations. Laboratory experiments were initiated to determine if the disease is infectious or if the lesions are the result of a nonspecific response by the scallop to environmental stress. (Contact: S.M. Bower)

Laboratory studies on the protozoan parasite *Mikrocytos mackini* that causes Denman Island Disease in oysters indicated that the disease does not develop in oysters held at 15°C but occurs and causes mortalities in oysters held at 10°C. The long prepatent period (three months) and the lack of infection at warmer temperatures may explain why this disease is only found in oysters in spring. (Contact: S.M. Bower)

Effect of Parasites on Sockeye Smolt Behaviour

Four parasites (the tapeworms *Eubothrium salvelini*, *Diphyllbothrium dendriticum*, and *Proteocephalus* sp., and the nematode *Philonema oncorhynchi*) that occur naturally in juvenile sockeye were found to influence the directional orientation of seaward migrating smolts from Great Central Lake, Vancouver Island. Interference of parasites with

smolt orientation could have implications for smolt survival. The results also suggest that parasite infection may account to some extent for the variability observed in migratory behaviour of smolts. (Contact: L. Margolis).

Sea Lice

Sea lice (parasitic copepods of the family Caligidae) are a significant cause of mortality among seawater-farmed salmon.

Studies were completed on the development, growth, and survival of *Lepeophtheirus salmonis* (the most important of the sea lice species) at various temperatures and salinities to achieve a better understanding of its biology. Among the three farmed salmon species, the order of susceptibility to infection was determined to be Atlantic salmon, chinook, and coho. Prior to testing the efficacy of Ivermectin as a treatment for sea lice, an experiment was initiated to assess the toxicity of this substance on salmonids. (Contacts: L. Margolis, M.L. Kent)

Parasites of Yukon River Chinook Salmon

Juvenile chinook salmon from 19 Canadian sites and five U.S. sites on the Yukon River were sampled for parasites to assess the potential of using parasites to distinguish among stocks, particularly between those from the upper (Canadian) and lower (U.S.A.) portions of the river. Although seven species of parasites were found, the fish were lightly parasitized and there were no significant inter-stock differences. The absence of the myxosporean brain parasite *Myxobolus* is notable because of its previously recognized value as a biological tag in other salmonid populations. (Contacts: L. Margolis, T.E. McDonald)

Science Support

Science Review
1989/90

Marine Division

67

The Marine Division provided ship, launch and depot support for the scientific and hydrographic programs conducted by the Science Sector, DFO fisheries patrol vessels and research conducted by other federal agencies and universities.

FRV CALIGUS: Home port: PBS
Length 17 metres; gross tonnage 41.36

The CALIGUS spent 188 operational days and steamed 4,833 miles in support of Biological Sciences Branch activities related to salmon, herring and shellfish in Rivers Inlet, the Gulf of Georgia and Howe Sound. The vessel was also used by the Pacific Geoscience Centre (PGC) for work in Knight Inlet.

FRV W.E. RICKER: Home Port: PBS
Length 58 metres; gross tonnage 1,105.52

For most of 1989/90, the W.E. RICKER was inactive, pending decisions on seaworthiness and funding for repairs. A total of 39 days and 5,541 miles were spent in support of hake, groundfish and rockfish surveys off the west coast of Vancouver Island.

JOHN P. TULLY: Home Port: IOS
Length 69 metres; gross tonnage 2,199

The JOHN P. TULLY steamed 24,538 miles in 203 days. The vessel's major cruise was in support of science activities in the Beaufort Sea from July through September. The vessel also supported the PGC, Defence Research Establishment Pacific, and the Royal British Columbia Museum, finishing the year with S.A.R. duties during the roe herring fishery.

PARIZEAU: Home Port: IOS
Length 64.3 metres; gross tonnage 1,314

The PARIZEAU steamed 21,153 miles in 195 days in support of work conducted by Ocean Physics, Ocean Chemistry, Tides and Currents, PGC, DOE, and the University of British Columbia. Three of the PARIZEAU's 15 cruises were to Ocean Station Papa.

VECTOR Home Port: IOS
Length 39.6 metres; gross tonnage 516

A total of 211 operational days and 13,712 miles were dedicated to Ocean Physics, Ocean Chemistry, Tides and Currents, Ocean Ecology, PBS, Environmental Protection Service, Defence Research Establishment Pacific and UBC projects.

RICHARDSON:

Home Port: IOS

Length 19.8 metres; gross tonnage 59.27

The RICHARDSON steamed 4,592 miles in 174 days in support of Hydrography and Simon Fraser University. The vessel also performed S.A.R. duties during the roe herring fishery.

Barges L.PACIFICA and PENDER:

Home Port: IOS

Between April and October, the PENDER was used to support oceanographic activities in the Storm Islands, Queen Charlotte Straits and Goletas Channel. The L. PACIFICA supported M.A.S.S. program field work in Barkley Sound between April and August.

Deck Machinery

Deck machinery staff continued to provide maintenance and support for winches and cranes aboard DFO vessels.

Depot Workshops

Electronic refit of four out of five Sooke Class vessels was completed and plans for upgrading the older patrol vessels are progressing. Over 1,200 work orders were completed.

The construction of the replacement vessel for the RICHARDSON, the R.B. YOUNG, was completed with the vessel scheduled to go into service in April, 1990. The ROBSON REEF, replacement vessel for the patrol vessel FALCON ROCK, is scheduled to be put into service in the Central Coast area in early June, 1990. Other construction underway is the DECIBAR replacement, due for completion in late summer, 1990.

Scientific Computing

Science Review
1989/90

69

Institute of Ocean Sciences

Approval and funding were obtained to upgrade the IOS central VAX computer system to a VAX 6000-310 which was installed in March, 1990.

The Compute Server, used for ocean modelling, was upgraded. Database applications, such as the User Tapes database and the Consumable Stores Inventory System, were improved and installed. The efficiency of all ORACLE database applications was also improved.

General policies for networking at IOS were developed and hardware and software for an IOS link to the BCnet high-speed research network and hence the CA*net and the US Internet, were acquired.

Scientific Computing staff participated in the development of Regional and CHS National Informatics plans.

The reorganization of scientific computing support staff continued. The position of Oceanographic Data Manager was established to standardize the data formats, processing and archiving of oceanographic data. As a first step, IOS adopted the Bedford Institute of Oceanography standards for data formats and installed BIO's software for processing and analysis of oceanographic data. (*Contact: K. Teng*)

Pacific Biological Station

Evaluation of methods to network Personal Computers (PC's) with the VAX resulted in the choice of Mobius software. Ethernet lines were installed in all offices in the PBS complex and Mobius software was installed on 100 PC's at PBS, West Van Lab and Cultus Lake. Communication between microcomputer and the mainframe computer is now much easier.

Activities in the next year will focus on data storage in the form of more disk space and CD-ROM technology, high speed communications links between DFO regional headquarters and PBS, improving West Van Lab link. Software upgrades for data management, analysis and reporting will have emphasis on using Standard query language (SQL) and providing geographic information. (*Contact: M. Marshall*)

Communications

Information requests from client groups, students and the general public were fulfilled. In addition, ongoing tour programs at the Pacific Biological Station and the Institute of Ocean Sciences continued to attract an increasing number of visitors, including school groups, tourists, service clubs, visiting scientists and the general public. A volunteer docent program was established at the West Vancouver Laboratory to accommodate requests for tours of that facility.

A "Partners in Education" agreement was developed and signed between the Pacific Biological Station and Wellington Secondary School. A total of 60 Biology 11 students were given tours of PBS and participated in one day "work experience" placements throughout the facility. Speakers were provided for a number of Career Day events held throughout the Nanaimo School District as were scientific staff for the B.C. Scientists in the Schools Program.

Communications staff also coordinated BSB participation in the West Vancouver Coho Festival and were involved in planning for the visit by Her Royal Highness Professor Dr. Princess Chulabhorn of Thailand to PBS.

Preliminary planning for Open Houses at both IOS and PBS scheduled for September 1990 was initiated.

Staff provided communications support for research activities related to the North Pacific high seas squid fishery and provided editorial support for a document submitted to the first North Pacific Driftnet Conference hosted by the B.C. Ministry of Agriculture and Fisheries.

Publications completed during 1989/90 included the Pacific Region Science Review for 1988/89. (*Contact: K.L. Francis*)

Management Services

Science Review
1989/90

71

Institute of Ocean Sciences

Support is provided to approximately 500 Science Sector and Marine Division personnel in the areas of purchasing, inventory control, vehicles, warehousing, Library services, telecommunications, records management and health, safety and security. Management Services Branch is responsible for the maintenance, repair, construction and upkeep of the Institute's buildings and grounds.

Work continued on enhancements to the marine facility, concentrating on drainage, concrete work and paving. Several construction projects related to health and safety issues were completed by Facilities Management.

All other areas of Management Services continued to play an active role in support of the Institute's programs. Health and safety issues, particularly the implementation of WHMIS continued to occupy considerable time. (*Contact: J.H. Coldwell*)

Pacific Biological Station/ West Vancouver Laboratory

Support is provided to research and operational programs in the areas of facilities management, purchasing, contracting, vehicles, warehousing, inventory control, library, publications, telecommunications, records management, stationery and general office.

A computerized card access control system replaced the standard keys at four major entry doors at PBS. Major improvements were made to the heating and ventilation system in the Annex. Asbestos was removed from the ceiling of the Lower Campus Warehouse, following decontamination and removal of the contents.

Service improvements included implementation of emergency travel advances and arranging minor non-scientific contracts in-house.

The Workplace Hazardous Material Information System (WHMIS) became operational.

Library staff actively participated in the initial draft of the WAVES II database standards.

Two 40 HP seawater pumps each rated at 1000 US gpm and a 12 inch intake line were installed at the West Vancouver Laboratory.
(Contact: W.B. Ross)

Personnel Services Branch

Personnel services are provided to approximately 800 employees located at IOS, PBS, West Vancouver Laboratory and other satellite facilities as well as the general public. This includes classification of positions, recruitment, selection and appointment, staff relations, training, human resource planning, employment equity and compensation and benefits. (Contact: L. Groves)

Publications 1989

Science Review
1989/90

Institute of Ocean Sciences

73

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96

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Permanent Staff 1989/90

Science Review
1989/90

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97

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Jackson, D.M.; B.Sc. (Victoria)	Schofield, A.J.
Jennings, M.J.	Schofield, B.D.; B.Sc. (Victoria)
Jodrell, D.A.	Sinnott, D.C.; B.Sc. (Victoria)
Johnson, B.A.; Dip. (BCIT)	Smedley, A.J.*; L. Cdr. RCN (Ret'd)
	Smith, A.; Master (FG)
	Smith, G.R.; B.A.Sc. (ME) (Brit. Col.), P.Eng.

Stephenson, F.E.; B.Sc. (Victoria)
Stolz, J.
Sutherland, N.A.; B.Sc. (Victoria)
Thompson, L.G.
Thomson, A.D.; Dip. (BCIT)
Thorn, A.J.**; B.Sc. (ME)
(Edmonton) P. Eng.
Tuck, B.D.; B.Sc. (Victoria)
Walker, J. C.**
Ward, M.M.; Dip. (BCIT),
B.A. (Lakehead)
Warthing, G.
Watt, B.M.
Wells, I.C.*; B.Sc. (Victoria)
Whincup, G.

Wingerter, B.**; B. Sc. (Victoria)
Willis, S.
Wollard, A.L.; B.Sc. (Victoria)
Woods, M.V.; Dip. (BCIT),
B.Sc. (Calgary)
Woodward, M.J.; B.Sc. (Victoria),
M.Sc. (Toronto)
Woolley, R.; Dip. (BCIT)
Yee, J.

*Left in 1989/90

**Joined in 1989/90

Ocean Physics

Division Chief:

Garrett, J.F.; B.A. (Harvard), Ph.D. (Brit. Col.)

Bigham, R.H.
Budgell, W.P.; B.A.Sc. (Waterloo),
M.Eng. (McMaster), Ph.D. (Waterloo)
Carmack, E.C.; B.Sc. (Arizona
State), Ph.D. (Washington)
Chase, G.W.; Dip. (BCIT)
Cooke, R.A.; Dip. (RCC)
Cummins, P.F.; B.Eng. (Concordia),
M.Sc. (Brit. Col.)
de Jong, C.; Dip. (VMTO)
Delacretaz, A.
Farmer, D.M.; B. Comm.,
M.Sc. (McGill), Ph.D. (Brit. Col.)
Foreman, M.G.;
Francis, D.B.; B.Sc. (Victoria)
Freeland, H.J.; B.A. (Essex),
Ph.D. (Dalhousie)
Gamble, F.P.
Gargett, A.E.; B.Sc. (Manitoba),
Ph.D. (Brit. Col.)
Gower, J.F.R.; B.A., M.A.,
Ph.D. (Cantab)
Green, J.W.; B.Sc. (Victoria)
Henry, R.F.; B.Sc. (Edinburgh),
Ph.D. (Cantab)
Holloway, G.; B.A., M.S.,
Ph.D. (California)
Johnston, P.; Dip. (BCIT)
Juhasz, T.A.
Kamitakahara, G.R.; B.Sc. (Toronto)
Kimber, P.M.
Koppel, A.W.
Lake, R.A.; B.Sc. (Brit. Col.),
M.Sc. (Washington)
Lee, D.K.; B.S. (Chosun, Korea),
M.S. (Oregon)

Lee, A.Y.P.; B.Sc. (Victoria)
Lewis, E.L.; B.Sc., M.Sc.,
Ph.D. (London)
Linguanti, J.; B.Sc. (Victoria)
Love, J.
Masson, D.
Melling, H.; B.Sc., M.Sc.,
Ph.D. (Toronto)
Minkley, B.G.; Dip. (BCIT)
Miyake, M.; B.S. (EE) (Drexel), M.S.,
Ph.D. (Washington)
Moorhouse, S.W.
Murty, T.S.; B.Sc., M.Sc. (Andhra),
M.S., Ph.D. (Chicago)
Perkin, R.G.; B.A.Sc., M.Sc. (Brit. Col.)
Pite, H.; B.Sc. (Victoria),
Ph.D. (Sydney)
Quay, L.
Richards, D.L.
Spearing, L.A.F.; B.Sc. (Brit. Col.)
Stucchi, D.J.; B.A.Sc. (York),
M.Sc. (Dalhousie)
Tabata, S.; B.A., M.A. (Brit. Col.),
D.Sc. (Tokyo)
Teichrob, R.C.; Dip. (BCIT)
Thomson, R.E.; B.Sc.,
Ph.D. (Brit. Col.)
Topham, D.R.; D.L.C., D.C.A.E.,
Ph.D. (Loughborough)
Wallace, J.S.; Dip. (SAIT)
Warnes, T.M.; Dip. (Camosun)
Yelland, D.R.

*Left in 1989/90

**Joined in 1989/90

Centre for Ocean Climatic Chemistry

Division Chief:

Wong, C.S.; B.Sc., M.Sc. (Hong Kong), Ph.D. (Scripps), Dip.
Mar. Sc. (UNESCO), F.R.S. Chem. (U.K.), F.C.I.C.

Bellegay, R.D.; Dip. (NAIT),
Assoc. Deg. in Oceanography
(Shoreline Community College)
Johnson, W.K.; Dip. (BCIT)

Page, J.S.; B.Sc. (Brit. Col.)
Smith, G.L.; Dip. (NAIT)
Soutar, T.J.; Dip. (BCIT)
Whitney, F.A.; B.Sc. (Brit. Col.)

Science Review
1989/90

99

Ocean Chemistry

Acting Head:

W.J. Cretney; B.Sc., Ph.D. (Brit.Col.), F.C.I.C.

Henderson, J.G.
Macdonald, R.W.; B.Sc., Ph.D.
(Dalhousie), F.C.I.C.
Macdonald, D.M.; B.A.Sc. (Brit.
Col.), Dip. (Camosun)
Mahood, H.W.²
McLaughlin, F.A.;
B.Sc. (Victoria)

O'Brien, M.C.; B.Sc. (Alberta)
Paton, D.W.; B.Sc. (Brit. Col.)
Rogers, I.H.²; B.Sc. (Queen's, Belfast),
M.Sc., Ph.D. (Brit. Col.)
Thompson, J.A.J.; B.Sc. (McMaster),
Ph.D. (Alberta), F.C.I.C.

Data Assessment

Division Chief:

Wilson, R.C.H.; B.Sc. (Simon Fraser), M.S. (Western Washington)

Giles, J.S.^{**}
Giovando, L.F.*; B.A., M.A.,
Ph.D. (Brit. Col.)
Smiley, B.D.; B.Sc.,
M.Sc. (Alberta)

*Left in 1989/90

**Joined in 1989/90

Biological Sciences Branch

(Pacific Biological Station, Nanaimo,
unless otherwise indicated)

Director:

Beamish, R.J.; Ph.D. (Toronto)

Steele, A.

Thompson, A.

Thomson, J.A.*; M.Sc. (McGill)

Salmon Dynamics

Section Head:

Beacham, T.D.; B.Sc. Hons. (Manitoba), Ph.D. (Brit. Col.)

Bailey, R.E.; B.Sc., M.Sc.
(Simon Fraser)

Baillie, S.; B.Sc. (Brit. Col.)

Bams, R.; B.Sc. Hons.,

Nat. Phil. Drs. (Leyden)

Barner, L.W.

Bernard, F.R.*; Ph.D. (London)

Bigg, M.A.; Ph.D. (Brit. Col.)

Cooke, K.D.; B.Sc. (Alberta)

Crabtree, D.

Davies, D.; B.Sc. (Brit. Col.)

Finnegan, B.; B.Sc. (Victoria)

Gjernes, T.; B.Sc. (Victoria)

Groot, C.; B.Sc., M.Sc. (Amsterdam),
Ph.D. (Leyden)

Hargreaves, N.B.; B.Sc. (Alberta),
Ph.D. (Dalhousie)

Healey, M.; Ph.D. (Aberdeen)

Holtby, L. B.; B.Sc. (Carleton),
Ph.D. (Toronto)

Hungar, R.M.; Fishing Master
(Vancouver Marine College)

Irvine, J.; B.Sc. Hons.,
M.Sc. (Brit. Col.), Ph.D. (Otago)

Kadowaki, R.; B.Sc. (McGill)

Lebrasseur, R.J.*; B.Sc., M.Sc.
(Brit. Col.), Ph.D. (Glasgow)

McKinnell, S.M.; B. Sc. (Victoria)

Morris, J.; B.Sc. (McGill),
M.Sc. (Concordia)

Mundie, H.; B. Sc. (Aberdeen),
Ph.D. (London)

Murray, C.B.; B.Sc.,
M.Sc. (Brit. Col.)

Olesiuk, P.; B.Sc. (Manitoba)

Patten, B.; Dip. Fish. Cult.
(Malaspina)

Shaw, W.; B.Sc. (Victoria)

Sherry, M.

Simpson, K.S.; B.Sc. (Victoria),
M.Sc. (Brit. Col.)

Tanasichuk, R.W.; B.Sc. Hons.,
M.Sc. (Alberta)

Waddell, B.; B.Sc.
(Simon Fraser)

Ware, D.; B.Sc., Ph.D.
(Brit. Col.)

Welch, D.; Ph.D. (Dalhousie)

Whiteaker, S.

* Left in 1989/1990

Salmon Production

Section Head:

Riddell, B.E.; B.Sc. (Guelph), Ph.D. (McGill)

Blackbourn, D.J.; B.Sc. (London),
M.Sc. (Southampton), Ph.D.
(Brit. Col.)

Carter, E.W.; Dip. Forest Tech.
(Alberta)

Cass, A.; B.Sc. (Brit. Col.)

Diewert, R.; B.Sc. (Brit. Col.)

Elder, C.A.

Enzenhofer, H.*; Dip. (BCIT)

Henderson, M.A.¹; B.Sc.
(Western), M.Sc. (Manitoba),
Ph.D. (Brit. Col.)

Holmes, M.

Hudson, G.

Hume, J.*; B.Sc. (Brit. Col.)

Hyatt, K.D.; Ph.D. (Brit. Col.)

Kronlund, R.; B.Sc. (Victoria)
M.Sc. (Guelph)

Lapl, L.; B.Sc. (Wisconsin), M.Sc. (Washington)
 MacIsaac, E.²; B.Sc. (Brit. Col.)
 MacLellan, S.⁶; B.Sc. (N. B.)
 Mikl, I.
 Morley, B.; B.Sc. (Victoria)
 Morton, K.⁶; B.Sc. Hons. (Brit. Col.)
 Mueller, C.⁶
 Mulligan, T.J.; Ph.D. (Florida State)
 Nagtegaal, D.; B.Sc. (Simon Fraser)
 Rankin, P.; B.Sc. (Victoria),
 M.Sc. (Brit. Col.)
 Rutherford, D.; B.Sc. (Brit. Col.)

Schnute, J.; Ph.D. (Stanford)
 Serbic, G.; Dip. (BCIT),
 B.Sc. Hons. (Brit. Col.)
 Shortreed, K.²; B.Sc. (Brit. Col.)
 Starr, P.J.; B.A. (Yale),
 M.Sc. (Brit. Col.)
 Stockner, J.G.²; B.A. (Augustana),
 Ph.D. (Washington)
 Traber, R.
 Wood, C.C.; B.Sc. (Simon Fraser),
 Ph.D. (Brit. Col.)

Science Review
 1989/90

101

Salmon Habitat

Section Head:

Levings, C.D.²; B.Sc., M.Sc. (Brit. Col.), Ph.D. (Dalhousie)

Andersen, B.; B.Sc. (Brit. Col.)
 Barnes, D.;
 Birtwell, I.²; B.Sc. Hons. (London),
 Ph.D. (Kings College)
 Brown, T.G.; B.Sc., M.Sc. (Brit. Col.)
 Brown, T.J.; B.Sc., M.Sc.
 (Simon Fraser)
 Choromanski, E.²; M.Eng. (Szczecin)
 Gordon, R.⁶; B.Sc. (Brit. Col.)
 Bravender, B.; B.Sc. (Victoria)
 Kruzynski, G.²; B.Sc., M.Sc. (Sir George
 Williams). Ph.D. (Brit. Col.)
 Lauzier, R.²; B.Sc. (Ottawa),
 M.Sc. (Simon Fraser)
 Macdonald, J.S.²; B.Sc. (Simon Fraser),
 Ph.D. (Western Ontario)
 Mack, C.⁶

Martens, D.⁶; B.Sc. (Brit. Col.)
 McAllister, C.D.; B.A., M.A. (Brit. Col.),
 Ph.D. (Washington)
 Morton, S.⁶
 Ogilvie, V.⁶
 Piercey, B.²; B.Sc. (Brit. Col.)
 Price, D.²
 Scrivener, C.; B.Sc., M.Sc. (Victoria)
 Servizi, J.⁶; M.Sc. (M.I.T.),
 Ph.D. (Washington)
 Shirvell C.; B.Sc. (Alberta),
 Ph.D. (Otago)
 Spohn, S.²; B.Sc. (Brit. Col.)
 Waldichuk, M.²; Ph.D. (Washington)
 Whitehouse, T.²; B.Sc. (Brit. Col.)
 Williams, I.; B.Sc. (Brit. Col.)

Groundfish

Section Head:

McFarlane, G.A.; B.Sc. (Winnipeg)

Andrews, W.; Dip. (Malaspina)
 Candy, J.; B.Sc. (Brit. Col.)
 Cooper, J.
 Davenport, D.⁶
 Fargo, J.; B.Sc. (Simon Fraser)
 Foucher, R.P.; B.Sc. (Victoria)
 Gillespie, G.E.; B.Sc. (Victoria)
 Hand, C.M.; B.Sc. (Victoria)
 Hoffos, P.; Dip. (BCIT)
 Johansson, T.; Dip. (BCIT)
 Kieser, R.; B.Sc. (Dalhousie) M.Sc.
 (N. B.) Ph.D. (Brit. Col.)

Leaman, B.M.; B.Sc. (Simon Fraser),
 M.Sc., Ph.D. (Brit. Col.)
 Mitton, W.
 Nott, J.; B.A. (UCD)
 Richards, L.J.; B.Sc. Hons.
 (Dalhousie), M.Sc., Ph.D. (Brit. Col.)
 Rutherford, K.; B.Sc. (Victoria)
 Saunders, M.; B.Sc. (Victoria)
 Scarsbrook, R.
 Smith, M.S.
 Stanley, R.D.; B.Sc. Hons.,
 M.Sc. (Brit. Col.)

Thomson, B.L.; B.Sc. (Victoria)
M.R.M. (Simon Fraser)
Tyler, A.V.; B.A. (Pennsylvania),
M.Sc., Ph.D. (Toronto)

Venables, N.L.
Winther, I.^{3*}; B.Sc. (Victoria)

*Left in 1989/1990

Fish Age Determination

Burke, M.
Charles, K.
Gillespie, D.; B.Sc. (Victoria)
Janz, S.; B.Sc. (Alberta)

MacClellan, S.E.; B.Sc. (Brit. Col.)
Little, D.
Rankin, J.; B.Sc. (Victoria)

Herring

Section Head:

Haist, V.; B.Sc. (Brit. Col.)

Fort, C.; B.Sc. (Brit. Col.)
Haegele, C.W.; B.Sc. (Calgary)
Hamer, L.; B.A. (Manitoba)
Hay, D.E.; B.Sc. Hons.,
Ph.D. (Brit. Col.)
McCarter, B.; B.Sc. (Brit. Col.)

Miller, D.; B.Sc. (Brit. Col.)
Roy, C.
Schweigert, J.F.; B.Sc. Hons.
(Toronto), M.Sc. (Manitoba)
Stocker, M.; B.Sc. (McGill), M.Sc.
(Guelph), Ph.D. (Brit. Col.)

Shellfish

Section Head:

Jamieson, G.S.; B.Sc. (McGill), M.Sc., Ph.D. (Brit. Col.)

Bourne, N.; Ph.D. (Toronto)
Boutillier, J.; B.Sc. (Alberta),
Teaching Cert. (Brit. Col.)
Campbell, A.; B.Sc. (McGill), M.Sc.
(Manitoba), Ph.D. (Simon Fraser)
Carolsfeld, W.; B.Sc. (Victoria)
Fulton, J.; B.Sc. (Brit. Col.)
Ginther, N.; B.Sc. (Simon Fraser)

Harling, W.
Head, S.
Heritage, D.G.; B.Sc. (Victoria)
Noakes, D.; B.Sc. Eng. (Guelph),
M.A.Sc., Ph.D. (Waterloo), P.Eng.
Phillips, A.; B.Sc. Hons. (Victoria)
Roy, C.
Whyte, J.N.C.; Ph.D. (Edinburgh)

Ocean Ecology

(Institute of Ocean Sciences)

Head of Division:

Denman, K.L.; B.Sc. (Calgary), Ph.D. (Brit. Col.)

Brinkhurst, R.O.; B.Sc., Ph.D., D.Sc.
(London)
Brown, R.M.; B.Sc. (Brit. Col.)
Forbes, J.R.; B.Sc. (Carleton),
M.Sc. (Alberta)

Mackas, D.L.; B.S., M.S.
(Washington), Ph.D.
(Dalhousie)
Moore, D.F.; B.Sc. (McMaster)
Stone, M.

Aquaculture Division

Division Chief (Acting):

Tebb, T.A.

Science Review

1989/90

103

Biotechnology, Genetics And Nutrition

Section Head:

Donaldson, E.M.²; B.Sc. (Sheffield), Ph.D. (Brit. Col.), D.Sc. (Sheffield), FRSC

Baker, I.J.²; Dip. (BCIT)

Ball, G.H.²

Booth, M.²

Devlin, R.H.^{2**}; B.Sc., Ph.D. (Brit Col.)

Dosanjh, B.²; B.Sc., M.Sc. (India),

M.Sc. (Brit. Col.)

Dye, H.M.²; B.S.A. (Brit. Col.)

Higgs, D.A.²; B.Sc. (Victoria), M.Sc.,

Ph.D. (Manitoba)

Humphreys, R.M.⁴

Johnston, G.E.⁴

Lamb, A.²; B.Sc. (Brit. Col.)

McBride, J.R.²; M.A. (Brit. Col.)

Solar, I.I.²; B.Sc. (Chile)

Stevens, T.A.^{**}; B.Sc. (Brit. Col.), M.Sc.

(Portland State)

Tuck, D.; B.Sc. (Brit. Col.)

Withler, R.; B.Sc., M.Sc. (Brit. Col.)

^{**}Joined 1989/90

Fish Culture

Section Head:

Clarke, W.E.; B.Sc. (Brit. Col.), M.Sc. (Toronto), Ph. D. (U.C. Berkely)

Blackburn, J.; B.A. (California)

Damon, W.; B.Sc. (Brit. Col.)

Groot, E.P.; B.Sc. (Victoria),

M.Sc. (Brit. Col.)

Jensen, J.; B.Sc. (Simon Fraser),

M.Sc. (Washington)

Kennedy, R.

Kreiberg, H.; B.Sc., M.Sc. (N. B.)

Shelbourn, J.E.; B.Sc.,

M.Sc. (Brit. Col.)

Solmie, A.

Fish Health and Parasitology

Section Head:

Margolis, L.; B.Sc., M.Sc., Ph.D. (McGill)

Baglo, P.

Bower, S.M.; B.Sc., M.Sc.,

Ph.D. (Guelph)

Evelyn, T.P.T.; B.S.A., M.S.A.

(Toronto), Ph.D. (Brit. Col.)

Hoskins, G.E.; R.T. (R.C.H.),

B.Sc. (Alberta)

Kabata, Z.*; B.Sc., Ph.D.,

D.Sc. (Aberdeen)

Kent, M.L.^{**}; B.Sc. (Humboldt State),

M.Sc. (San Diego State)

Ph.D. (California)

Ketcheson, J.E.; B.Sc. (Alberta)

Kleser, D.; B.Sc., M.Sc. (Dalhousie)

McDonald, T.E.; B.Sc. (Brit. Col.)

Meyer, G.R.; Dip. Fish Cult. Tech. (Malaspina)

Mullen, K.E.; B.Sc. (Victoria)

Prosperi-Porta, G.; Dip. Chem. Analyst., Paolo

Parodi Delfino, Collefero

Traxler, G.S.; B.Sc. (Washington)

Westby, C.M.; R.T. Can. Soc. Med.

Technol. (BCIT)

Whitaker, D.J.; B.Sc. (Victoria)

* Left in 1989/1990

^{**} Joined in 1989/1990

Marine Division

Institute of Ocean Sciences

Gibb, D.E.; C.D.

Adams, G.
Bent, I.
Briese, C.
Crayton, M.I.*
Cullen, L.T.**
Doyle, D.A.*
Fitch, L.A.H.; Master H.T.
Irving, B.G.; Master H.T.
Murray, B.;
(350 Ton Endorsement)

Nelson, A.G.; 2nd Mate H.T.
(350 Ton Endorsement)
Parkinson, R.W.; Engineer 1st Class;
Member, Institute of Marine Engineers
Souliere, V.P.
Winterburn, G; Engineer 1st Class;
Member, Institute of
Marine Engineers

Pacific Biological Station

Marine Support

Parks, J.

Deck Machinery

Bradbury, J.D.

Institute Workshops

Badminton, E.C.
Barlow, L.
Bell, W.
Ennis, J.F.
Green, G.E.
Gurney, J.P.

Ingram, T.W.
Nelson, B.J., Foreman
Robson, W.J.
Smith, F.V., Supervisor
Smith, G.J.
Williams, P.D.

Scientific Computing

Institute of Ocean Sciences

Head: Teng, K.; B.A.Sc., M.A. (Brit. Col.)

Johns, R.E.; B.Sc. (Victoria), M.Sc. (Brit. Col.)
Oraas, S.R.; B.A.Sc., M.A.Sc. (Brit. Col.)
Smith, L.J.; B.Sc. (Simon Fraser)

Pacific Biological Station

Hamer, M.; B.Sc. (Manitoba)
Hamer, T.
Kuhn, B.R.
Marshall, M.; B.A. (Brit. Col.)

Science Review
1989/90

105

Communications Branch

Francis, K.L.; B.A. (Victoria) - PBS

Management Services Division

Institute of Ocean Sciences

Chief: Coldwell, J.H.

Cooper, B.J.
Curtis, J.N.
Doxey, K.
Drysedale, A.E.
Gent, C.E.
Grills, C.J.
Hope, T.
Keding, L.M.
Kroeger, K.

Lafortune, A.J.; B.A. (Manitoba)
MacMillan, B.C.
Paget, Ruth**
Thompson, R**
Thomson, L.S.C.; B.A. (Sask.),
B.L.S. (Brit. Col.)
Tillie, D.G.
Tubman, D.**
Van Eyk, W.J.

Pacific Biological Station/West Vancouver Laboratory

Head: Ross, W.B.; Dip. NBIT

Bayntun, G.
Bolton, P.
Booth, B.; Engineer 4th Class
Chu-Joy, H.²
Coggins, S.
Fahr, M.
Hawthornthwaite, M.
Houlihan, C.
Humphreys, S.
Irving, P.
Keller, S.²
Lyons, E. **
Matheson, R.²
McManlman, D.; Engineer 4th Class
Miller, G.; B.A. Hons (Calgary),
B.L.S. (Brit. Col.)

Muhlfellner, E. ; Engineer 4th Class
Olson, P.; B.A. Hons. (Simon Fraser),
M.L.S. (Brit. Col.)
Owen, D.
Pierce, D.
Renner, T.; Engineer 2nd Class
Ring, P.; Engineer 3rd Class
Stead, L.; Engineer 4th Class
Vogt, P.*

Williams, R.; Engineer 4th Class
Zanatta, Al.²

*Left in 1989/90

**Joined in 1989/90

Comptroller's Branch
Institute of Ocean Sciences

Brydon, T.

Pacific Biological Station

Corriveau, J.; B. Comm. (Brit. Col.)

Personnel Branch
Institute of Ocean Sciences

Personnel Administrator:
Groves, L.D.; Dip. (Victoria)

Emberley, C.
Filko, L.
Gallipeau, F.
Olauson, E.J.
Pritchard, E.
Renstrom, M.
Reynolds, B.

Pacific Biological Station

Dale, E.
Ford, Debi*
Morrow, K.

- 1-DFO Headquarters, Vancouver
- 2-West Vancouver Laboratory
- 3-Prince Rupert
- 4-Rosewall Creek
- 5-Vancouver waterfront
- 6-Cultus Lake
- 7-New Westminster
- 8-Institute of Ocean Sciences

*Left in 1989/90

1989/90

ORGANIZATION CHART

1989/90

Department of Fisheries and Oceans
Science Branch, Pacific Region

```
graph TD
    D[Director Biological Sciences  
R.J. Beamish] --> A[Aquaculture Division  
A/Head T. Tebb]
    D --> B[Fish Health & Parasitology  
L. Margolis]
    D --> C[Fish Culture  
W.E. Clarke]
    D --> D[Biotechnology, Genetics and Nutrition  
E.M. Donaldson]
    D --> E[Groundfish  
G.A. McFarlane]
    D --> F[Shellfish  
G.S. Jamieson]
    D --> G[Herring  
V. Haist]
    D --> H[Ocean Ecology  
K.L. Denman]
    D --> I[Chief Data Assessment  
R.C.H. Wilson]
    I --> J[BSB Science Coordinator  
A/J. Boutillier]
    I --> K[Salmon Dynamics  
T.D. Beacham]
    I --> L[Salmon Production  
B.E. Riddell]
    I --> M[Salmon Habitat  
C.D. Levings]
    I --> N[Director, Science  
J.C. Davis]
    N --> O[Director General  
P.S. Chamut]
    O --> P[ADM Pacific & Freshwater Fisheries  
P. Asselin]
    O --> Q[ADM Science  
A/W. Doubleday]
    N --> R[Secretary  
L.J. McDonald]
    N --> S[Director Physical & Chemical  
A/J. F. Garrett]
    S --> T[Ocean Physics  
J.F. Garrett]
    S --> U[Centre for Ocean Climatic Chemistry  
C.S. Wong]
    S --> V[Ocean Chemistry  
W. Cretney]
    S --> W[Computing Services  
K. Teng]
    S --> X[NOGAP  
R.W. MacDonald]
    S --> Y[Field Hydrology  
R.W. Sear]
    S --> Z[Chart Preparation  
W.S. C.]
    S --> AA[Tides & W.J.]
    S --> AB[Electronic Liaison  
T.A. C.]
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